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Cover illustration: The 'Freshwater Crayfish' (most likely *Astacopsis tricornis*) in Gould's *Sketchbook of Fishes* (Gould c. 1832). Watercolour on paper by Willian Buelow Gould, painted at Macquarie Harbour. [Reproduced with the permission of the Allport Library and Museum of Fine Arts, Tasmanian Archive and Heritage Office.].

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VEGETATION CHANGE ON AN URBAN COASTAL DUNE SYSTEM

by Thomas Guy and Jamie B. Kirkpatrick

(with one text-figure, six plates and one table)

Guy, T. & Kirkpatrick, J.B 2018 (14:xii):Vegetation change on an urban coastal dune system. *Papers and Proceedings of the Royal Society of Tasmania* 152: 1–8. ISSN: 0080–4703. Discipline of Geography and Spatial Sciences, School of Technology, Environments and Design, University of Tasmania, Private Bag 78, GPO Hobart, Tasmania, Australia 7001 (TG, JK*). * Author for correspondence. Email: J.Kirkpatrick@utas.edu.au

Coastal environments, not directly transformed by urbanisation but within an urban matrix, can be transformed by changes in climate, invasive species and plantings. We assess changes in vegetation structure since European settlement and changes in native species abundance since 2003 on the cuspate dune complex at Lower Sandy Bay, Tasmania. The pre-European vegetation of the cuspate forehead seems likely to have been grassland dominated by *Spinifex sericeus* and *Austrofestuca littoralis* on the foredunes and *Eucalyptus viminalis* open-forest with a shrubby to grassy understorey on the older dunes. Some trees of *E. viminalis* still occur on the dune system, together with many elements of the original understorey. The foredune native vegetation had been replaced by *Ammophila arenaria* closed-grassland by 2003. Much of this grassland was invaded by the native shrub, *Acacia longifolia*, by 2017. Between 2003 and 2017 almost all native shrub species increased in abundance. Succulent, grass and herb species suffered decline. Increased competition with exotic species, changes in disturbance regimes and decreases in fire frequency in the coastal area are most likely to have influenced the changes in native species distributions.
Key Words: coastal vegetation, dune system, Long Beach Tasmania, native coastal plant species, urbanisation

INTRODUCTION

Coastal environments are dynamic systems which are constantly responding to changes in climate, weather, landforms, marine conditions and biota, as well as to anthropogenic factors, for example urban development, recreational uses and the introduction of exotic species (Harvey & Caton 2003, Smith & Doherty 2006). Dune systems are recognised globally as being important for both biodiversity and human use (Ranwell 1972). Sand dune vegetation is dependent on climatic influences; wind and precipitation are the two most important climatic influences on sand dune vegetation composition (Ashkenazy *et al.* 2012). The highly disturbed nature of coastal environments leads to a constant state of colonisation (Ranwell 1972). Thus, areas of dry coastal vegetation are vulnerable to invasion by exotic species (Kirkpatrick 1974, O'Shea & Kirkpatrick 2000, Ivey-Law & Kirkpatrick 2015).

In the remnant coastal vegetation of Australia, native species richness decreases with urbanisation, whereas, exotic species become proportionally more common (McKinney 2002). Urban development is often accompanied by physical modification to the coastline, increased ground disturbance, invasion of exotic species and general deterioration of the native vegetation (Harris 1991).

Vegetation zonation caused by strong environmental gradients in coastal dune systems allows for the coexistence of diverse vegetation communities in small areas (Biondi 2007) as has been observed in several places on the Tasmanian coast (Bowden & Kirkpatrick 1974, Chladil & Kirkpatrick 1989). There is a large pool of native species available for colonisation (Kirkpatrick & Harris 1995), as well as a large pool of exotics (Gill 2001, O'Shea & Kirkpatrick 2000). On the coast to the south of the cuspate forehead, there has been a well-documented temporal increase in exotic plant richness, as urbanisation has proceeded (O'Shea & Kirkpatrick 2000).

Changes in the abundance of particular lifeforms can lead to changes in the species richness of other lifeforms. Increases in abundance or density of trees, shrubs and bushes is referred to as woody encroachment (Ratajczak *et al.* 2012) or woody thickening (Ivey-Law & Kirkpatrick 2015). The transition from heathland to scrub is a process in which the tallest species exclude other shade intolerant species under a closed canopy, resulting in an overall reduction in species richness (Bargmann & Kirkpatrick 2015).

The aim of the present study is to document vegetation change since European settlement to determine whether native coastal plant species have continued to decline on an urbanised coast, as predicted by O'Shea & Kirkpatrick (2000), and to determine whether lifeform predicts the magnitude of change.

METHODS

Study area

The study area is located at Lower Sandy Bay, Hobart, Tasmania. The site extends from Blinky Billy Point (42°54'50.9"S, 147°21'39.2"E) to the western end of Nutgrove Beach (42°54'31.5"S, 147°20'52.9"E) (fig. 1). Rocky coasts adjoin the beach at the southern end of Long Beach, Blinking Billy Point and the southeast end of Nutgrove Beach. Sandy Bay Point is a cuspate forehead, formed by longshore drift from both north and south. Nutgrove and Long beaches have been important areas for recreation by the public since the 1830s. Perceived loss

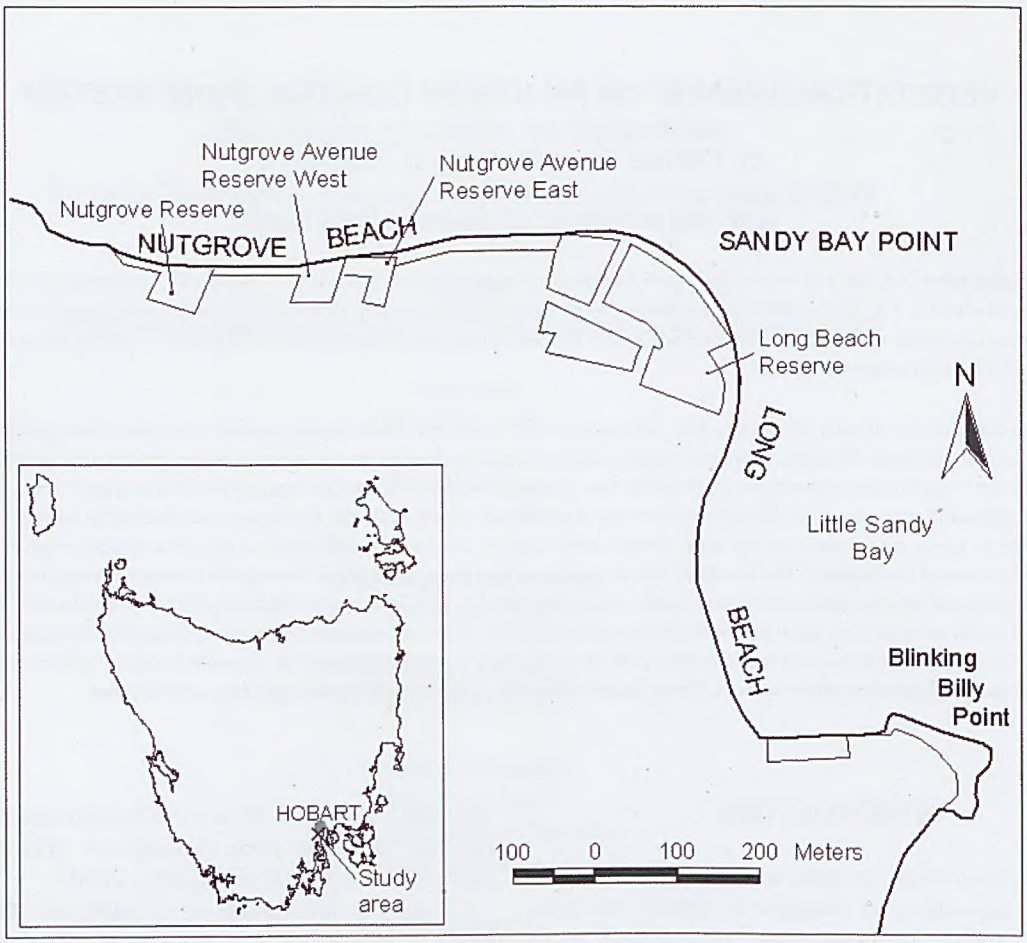

FIG. 1 — Study area.

of sand in the area has been an ongoing issue. Since 1834 the area has undergone natural deposition of sand and supplementary anthropogenic deposition of material in the process of land reclamation (Cruise 1978).

Data collection

Historical images of the area were obtained from the Tasmanian Library Archive and Heritage Office and the Tasmanian Government's Linc archive website. Photographs were inspected for identifiable plant species and growth forms and compared between successive years. The 2003 data were collected by a University of Tasmania class, under the close supervision of the junior author, who used Global Positioning Devices (GPS) to record the individual locations of every native vascular plant species in the area. The native species in the reserves, and within 15 m of the coast for those species outside of the reserved areas, were recorded (fig. 1). Twenty-seven native species were recorded. Repeat data collection and mapping was carried out from February to April 2017 and the numbers of individuals compared between the two dates. Areas containing planted native species were excluded from data collection, for example, garden beds. However, individuals that had naturalised from plantings were included.

RESULTS

Early twentieth century photographs (pls 1, 2, 3) strongly suggest that the stable part of the dune system once supported the same type of coastal forest, dominated by *Eucalyptus viminalis*, that survives on Rheban Spit, east coast of Tasmania (Bowden & Kirkpatrick 1974).

There have been substantial changes in the morphology of the study area since 1946. The most notable change has occurred to the cuspate forehead at the northern end of Long Beach, which has changed in shape. A seawall and concrete walkway have been constructed behind Long Beach. The most obvious change to the vegetation was the replacement of native sand binders (probably *Spinifex sericeus* and *Austrofestuca littoralis*) with the introduced marram grass (*Ammophila arenaria*) on the cuspate forehead of Sandy Bay Point (pls 4, 5, 6). *Spinifex sericeus* and *A. littoralis* are distinguished from *A. arenaria* in the aerial photographs by their sparse growth form and mounded topography; *A. arenaria* typically develops 100% cover and linear dunes (Hayes & Kirkpatrick 2012) (pl. 4). There appear to be fewer mature trees present in the 2003 and 2017 aerial photographs than in 1946, judging from the degree of canopy closure and the area occupied by forest (pls 4, 5, 6). Tree abundance was similar in 2003 and 2017,

PLATE 1 — Long Beach (1939) coastal eucalypt woodland with shrubby understorey as photographed from the southern end of Long Beach Sandy Bay. Some of the trees on the point to the right have survived to the present and are *Eucalyptus viminalis*. Digitised item from: Tasmanian Library, Tasmanian Archive and Heritage Office https://stors.tas.gov.au/AUTAS0016125412692.

PLATE 2 — Long Beach (1939) coastal *Eucalyptus viminalis* woodland with shrubby understorey. Digitised item from: Tasmanian Library, Tasmanian Archive and Heritage Office https://stors.tas.gov.au/AUTAS0016125412452.

PLATE 3 — Long Beach (pre-1939); coastal *Eucalyptus viminalis* woodland with shrubby understorey on sand dunes at rear. Digitised item from: Tasmanian Library, Tasmanian Archive and Heritage Office https://stors.tas.gov.au/AUTAS0016125412452.

PLATE 4 — Composite photograph of study site (1946). The hummocky grassland on the cuspate forehead is typical of native sand-binders. Sourced from Hobart run 8 1946. 11074–11076.

PLATE 5 — Google Earth image of study site (2003).

PLATE 6 — Google Earth image of study site (2017).

with 63 and 65 respectively (table 1). Shrubs noticeably thickened between 2003 and 2017 (pls 5, 6).

There were three species (*Acacia dealbata, A. melanoxylon* and *Allocasuarina verticillata*) that had the same abundance in 2003 and 2017 (table 1). Ten taxa were observed to have increased in abundance since the 2003 survey: *Acacia longifolia* subsp. *sophorae, Calocephalus brownii, D. brevicaulis, Einadia nutans, Elymus scaber, Eucalyptus viminalis* subsp. *hentyensis, Pteridium esculentum, Rhagodia candolleana, Sarcocornia quinqueflora and Tetragonia implexicoma* (table 1).

There were 12 species observed that had decreased in abundance or were no longer present in the area (table 1): *Acaena novae-zelandiae, Austrodanthonia setacea, Austrostipa flavescens, Bursaria spinosa, Carpobrotus rossii, Cynoglossum australe, Dichelachne crinita, Dichondra repens, Eucalyptus globulus, Oxalis perennans, Poa labillardierei* and *Senecio quadridentatus. Cynoglossum australe* is the only species listed as rare or threatened that was located in the study area. There were six individuals recorded in 2003 and only three individuals recorded in 2017.

TABLE 1
Authority, family, lifeform and number of individuals in 2003 and 2017 for native species in the study area.

Species	Family	Vegetation type	2003	2017
Acacia dealbata Link subsp. *dealbata,* Enum.	Mimosaceae	Tree	1	1
Acacia melanoxylon R.Br.	Mimosaceae	Tree	1	1
Acacia longifolia (Andrews) Willd. subsp. *sophorae* (Labill.) Court	Mimosaceae	Shrub	77*	219
Acaena novae-zelandiae Kirk	Rosaceae	Herb	1	0
Actites megalocarpus (Hook.f.) Lander	Asteraceae	Herb	0	2
Allocasuarina verticillata (Lam.) L.A.S.Johnson	Casuarinaceae	Tree	0	3
Allocasuarina littoralis (Salisb.) L.A.S.Johnson	Casuarinaceae	Tree	3	4
Atriplex cinerea Poir.	Chenopodiaceae	Herb	6	5
Austrodanthonia setacea (R.Br.) H.P.Linder	Poaceae	Grass	50*	1
Austrostipa flavescens (Labill.) S.W.L.Jacobs & J.Everett	Poaceae	Grass	24	1
Banksia marginata Cav.	Proteaceae	Shrub	0	1
Bursaria spinosa Cav. subsp. *spinosa*	Pittosporaceae	Shrub	12	10
Calocephalus brownii (Cass.) F.Muell.	Asteraceae	Herb	1	5
Carpobrotus rossii (Haw.) Schwantes	Aizoaceae	Succulent	12	0
Cynoglossum australe R.Br.	Boraginaceae	Herb	6	3
Dianella brevicaulis (Ostenf.) G.W.Carr & P.F.Horsfall	Liliaceae	Herb	2	6
Dichelachne crinita (L.f.) Hook.f.	Poaceae	Grass	3	0
Dichondra repens J.R.Forst. & G.Forst.	Convolvulaceae	Herb	2	0
Distichlis distichophylla (Labill.) Fassett	Poaceae	Grass	2	0
Dodonaea viscosa Jacq. subsp. *spatulata* (Sm.) J.G.West	Sapindaceae	Shrub	0	5
Einadia nutans (R.Br.) A.J.Scott	Chenopodiaceae	Herb	4	8
Elymus scaber (R.Br.) Á.Löve	Poaceae	Grass	2	4
Eucalyptus globulus Labill.	Myrtaceae	Tree	37*	35
Eucalyptus viminalis Labill. subsp. *hentyensis* Brooker & Slee	Myrtaceae	Tree	20	22
Isolepis nodosa (Rottb.) R.Br.	Cyperaceae	Sedge	0	4
Myoporum insulare R.Br.	Myoporaceae	Shrub	0	19
Oxalis perennans Haw.	Oxalidaceae	Herb	4	0
Poa labillardierei Steud. var. *labillardierei*	Poaceae	Grass	6	5
Pteridium esculentum (G.Forst.) Cockayne	Dennstaedtiaceae	Fern	24*	60
Rhagodia candolleana Moq.	Chenopodiaceae	Shrub	60*	189
Sarcocornia quinqueflora (Bunge ex Ung. -Sternb.) A.J.Scott	Chenopodiaceae	Herb	1	4
Senecio quadridentatus Labill., Nov. Holl.	Asteraceae	Herb	13	5
Tetragonia implexicoma (Miq.) Hook.f.	Aizoaceae	Herb	12	87
Total			386	709

*approximate values as counted from the 2003 maps.

Five out of six shrub species increased in density between 2003 and 2017 (table 1). Five out of the six grass species have decreased in abundance since 2003. The succulent species (*Carpobrotus rossii*) was recorded during the 2003 survey but was not found during the subsequent survey in 2017. *Pteridium esculentum* was the only species of fern observed. It has increased in density in the area. Three of the species (*Einadia nutans, Rhagodia candolleana* and *Tetragonia implexicoma*) that have increased in abundance produce a fleshy-fruit (table 1). These three species also have the ability to use other vegetation for support.

DISCUSSION

Shrub species have increased in density in many different environments since the 1940s (Ivey-Law & Kirkpatrick 2015, Mitchard *et al.* 2009, Ratajczak *et al.* 2012, Bargmann & Kirkpatrick 2015). Woody thickening causes shrub species to outcompete smaller plant species, such as herbs. This is evident in Sandy Bay in the results from the changes in abundance of small herbs surveyed in 2003 and 2017. Ivey-Law & Kirkpatrick (2015) made similar observations at the decadal scale in an urban coastal reserve in Melbourne, Australia.

Acacia longifolia has increased in abundance in the area since 2003 (table 1). The increase of *A. longifolia* is thought to be due to natural expansion from remnants, as no information could be obtained about planting of this species in the area. *Acacia longifolia* is a fire-sensitive short-lived species that relies on disturbance to regenerate (Hazard & Parsons 1977). Although *A. longifolia* depends on bare ground for regeneration, the expansion of the species has been attributed to decreasing disturbance by both fire and grazing in coastal grasslands environments of New South Wales (Costello *et al.* 2000). *Acacia longifolia* can rapidly form closed stands that suppress the growth of shorter species, thereby reducing biodiversity regimes (Clay & Schneider 2000, Costello *et al.* 2000). We suggest that *A. longifolia* should be prevented from achieving total dominance, especially in places that support rarer species, such as *C. australe*. Management of *A. longifolia* should be conducted without the use of fire, as the area is highly developed and in close proximity to residential areas. Also, fire stimulates the regeneration of *A. longifolia* (Costello *et al.* 2000). Mechanical removal of occasional single plants of *A. longifolia* may be a more suitable management strategy for this area.

The expansion of shrub species has been related to decreases in the frequency of fire (Roques *et al.* 2001, Sankaran *et al.* 2005, Watson *et al.* 2009). The suburbanisation of the Hobart coast has had a direct impact on fire regimes. The decrease in fire frequency has allowed the invasion of fire-sensitive exotics into nearby coastal cliff vegetation (O'Shea & Kirkpatrick 2000). Watson *et al.* (2009) observed that exotic species were most common in areas with infrequent fire events in coastal woodland in New South Wales.

Species that have seed dispersed by birds are increasing in abundance. Birds and ants disperse *Acacia longifolia* seeds (O'Dowd & Gill 1986). *Tetragonia implexicoma, Einadia nutans* and *Rhagodia candolleana* all possess fruit consumed by birds (Groves 2008, Lepschi 1993, Lindsay & Meathrel 2008). *Tetragonia implexicoma, E. nutans* and *R. candolleana* can smother other vegetation (Harris & McKenny 1999). Both their dispersal mechanisms and the ability to smother other plants provide a competitive advantage.

Both introduced and native species have the potential to become weedy under the right conditions. It is important to address management at the earliest opportunity rather than once the vegetation becomes established (Hobbs & Humphries 1995). A number of exotic species were observed during the vegetation sampling. The exotic species which pose the greatest threat to the natives are discussed in greater detail in the following paragraphs.

Marram grass (*Ammophila arenaria)* has established extensively throughout the study area. *Ammophila arenaria* has become very common in coastal regions of Australia since it was introduced to stabilise mobile dunes (Hilton *et al.* 2006). *Ammophila arenaria* is highly invasive and as a threat to the ecology of dune systems (Hilton *et al.* 2005, Wiedemann & Pickart 2004). The early aerial photographs (pl. 1) indicate native sand-binders where *A. arenaria* is now ubiquitous. The exclusion of the native sand-binder by *A. arenaria* drives changes in shape and structure of dune systems (Hilton *et al.* 2006, Hayes & Kirkpatrick 2012). The replacement of native sand-binding species by more competitive exotic sand-binding species facilitates the expansion of shrub species in Tasmanian coastal sand dune systems (Hayes & Kirkpatrick 2012).

Although the exotic tree, *Pinus radiata,* may outcompete other species, an understorey of predominantly native species under *P. radiata* occurs in some situations, such as plantations invaded by rainforest species (Brockerhoff *et al.* 2003) or in the zone of suppression of weed growth by root competition under isolated roadside trees (Kirkpatrick & Gilfedder 1998). Maintaining *P. radiata* in the area may provide habitat for some small herbs that would otherwise be excluded by competition from more vigorous plants.

At Rheban spit on the east coast, which shares a similar geomorphology and climate to Lower Sandy Bay, the dominant tree species is *E. viminalis* on the dunes (Bowden & Kirkpatrick 1974). The coastal woodland shown in the aerial and historic photographs is dominated by *E. viminalis,* as is indicated by the presence of trees of this species that are still extant.

Although all the species sampled in this study are native to the local area, there are areas of planted native vegetation. In a study of a similar area, Ivey-Law & Kirkpatrick (2015) refer to this process as ecological gardening. Ecological gardening may not have the ability to return the vegetation to a pre-European state, but it may be useful in order to maintain locally uncommon species (Ivey-Law & Kirkpatrick 2015).

Remnant vegetation in urban areas is often important for maintaining biodiversity as well as for human recreation (O'Shea & Kirkpatrick 2000). We suggest that *Cynoglossum*

australe be propagated from seed from the surviving plants and planted. The native garden beds in the Hobart City Council reserves would be suitable for planting the species.

As each individual native plant was counted, it is important to note that there is the potential for some individuals to be missed. Given the small size of the study area, the authors are confident that the results have a high degree of accuracy.

The current study sampled standing plants only, whereas the total population of many species on the site may comprise both standing plants and soil seed banks. Therefore, inferences about change address change in the standing plant populations, not necessarily the total population.

CONCLUSION

Urbanisation and coastal development place considerable pressure on native vascular plant species. The sample site (Sandy Bay, Tasmania) in this study has experienced substantial change since the mid-twentieth century; as demonstrated by the comparison of aerial, historic and present-day photographs of the area, together with the species maps produced in 2003 and again in 2017. The major changes in the vegetation have been the increase in shrub abundance, which has similarities to other coastal systems. The life forms that have suffered the most decline are succulent, grass and herb species. The loss of the native sand-binding species from the foredunes may have contributed to changing the shape and structure of the dune system, which has led to changes in the vegetation community. The lack of fire in the area in recent times may also be a major contributing factor to shrub expansion.

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SHORT-TERM RECOVERY OF CUSHION PLANT COMMUNITIES AFTER FIRE ON THE CENTRAL PLATEAU, TASMANIA

by Morgan C. Harding and Jamie B. Kirkpatrick

(with two text-figures, five plates and two tables)

Harding, M.C. & Kirkpatrick, J.B. 2018 (14:xii) Short-term recovery of cushion plant communities after fire on the Central Plateau, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 152: 9–15. ISSN: 0080–4703. Discipline of Geography and Spatial Sciences, School of Technology, Environments and Design, University of Tasmania, Private Bag 78, GPO Hobart, Tasmania, Australia 7001 (MCH, JK*). * Author for correspondence. Email: J.Kirkpatrick@utas.edu.au

There is slow or no regeneration of many Tasmanian alpine plant species after fire. At the decades scale cushion plants recover well, but there are no data on their short-term recovery. We determine the recovery of individual cushion bolsters and bolster communities at three locations on the Central Plateau of Tasmania burned less than five years before our repeat photography. Most cushions were scorched at the surface and perimeter rather than deeply combusted. Except where the bolsters were most intensively burnt, they revegetated within two years of fire. Cushion species extended their cover on the burned bolster surfaces at greater than twice the rate of all other species. Cushion segments that appeared to be deeply combusted during fire did not recover vegetatively.

Key Words: cushion plant, bolster plant, fire recovery, Tasmania.

INTRODUCTION

Bolsters are a dense assemblage of cushion plant individuals that coalesce to form a single sub-hemispherical structure (Curtis 1963, Gibson 1991, Kirkpatrick 1997). Due to their compaction and extremely short internodes, bolsters have a smooth, hard surface that may extend up to one or more metres in diameter and can be composed of many individuals and species (Curtis 1963, Gibson 1991, Kirkpatrick 1997). The Tasmanian endemic, *Abrotanella forsteroides* (Hook.f.) Benth., is the characteristic cushion of the eastern mountains, including the Central Plateau, where it is often mixed in bolster mosaics with a glaucous cushion, *Pterygopappus lawrencei* Hook.f. (Kirkpatrick 1997). *Dracophyllum minimum* F.Muell., *Phyllachne colensoi* (Hook.f.) Bergr. and *Donatia novae-zelandiae* Hook.f. are other frequent and widespread cushion species (Kirkpatrick *et al.* 1985, Kirkpatrick 1997), roughly distributed east to west respectively across the central and western mountains (Kirkpatrick 1982).

Efficient mechanisms for water uptake and a high absorption capacity, allow cushion bolsters to maintain a high water content (Gibson 1991). High water content and a smooth surface combine to make combustion rare (Kirkpatrick 1997). Adventive buds below the surface in *Abrotanella*, *Donatia* and *Phyllachne* cushions enable re-sprouting of foliage after complete surface heat-scorch (Kirkpatrick 1997).

A low fire frequency in Tasmanian alpine areas has allowed fire-intolerant species to dominate much of the landscape (Kirkpatrick *et al.* 2002, Kirkpatrick *et al.* 2010). With the exception of *Dracophyllum minimum*, cushion plants are resilient to fire at the decades scale (Kirkpatrick & Dickinson 1984, Kirkpatrick *et al.* 2002, Kirkpatrick *et al.* 2010, Kirkpatrick & Bridle 2013). Fire may be necessary to prevent their loss by smothering by taller species in some of the more productive parts of their ranges. We have no data on short-term bolster community recovery after fire. Mean annual temperature has increased while mean annual rainfall has decreased since 1970 (Calder & Kirkpatrick 2008, Bureau of Meteorology 2018). Warming and drying has led to increased fire frequency and area burned as predicted by King *et al.* (2013). Extensive fires occurred on the Central Plateau in 2013 (7000 ha) and 2016 (13 000 ha). There was public alarm at the potential loss of Pencil Pines (*Athrotaxis cupressoides* D.Don) and cushion plants (Press 2016), so it is important to understand the contingencies of short-term recovery.

The present study documents changes in individual cushion bolsters and bolster communities at three locations in the Central Plateau region of the Tasmanian Wilderness World Heritage Area burned 1–4 years previous to final observations.

METHODS

Study area

Three sets of photographs were taken of cushion bolsters and cushion bolster communities at sites burned either in 2013 or 2016. The Lake Mackenzie study site is located in the Central Plateau Conservation Area south of Mt Parmeener on the Great Western Tiers escarpment. The area was burned between 19 January 2016 and 27 January 2016. The surface geology of this area is Jurassic dolerite. The Poatina study site is situated slightly southeast of Cramps Bay and adjacent to the Poatina Road within the Great Lake Conservation Area. The fire burned between 29 November 2012 and 6 January 2013. The study area was very close to the point of ignition. The surface geology of this area is Jurassic dolerite. The Walls of Jerusalem study area is situated within the Walls of Jerusalem National Park on the western edge of the Central Plateau, with The Temple forming the eastern pillar of Damascus Gate, opposite Solomon's Throne. The area was burned on 3 January 2013. The surface geology

of the study site is a finely textured facies of the Parmeener supergroup of Permian/Triassic rocks.

Data collection

Shortly after each of the three fires, oblique photographs were taken of individual bolsters and bolster communities (table 1). These scenes were rephotographed in March and April 2017 (table 1). Location and orientation of each scene were recorded using a GPS and magnetic compass.

Analysis

Due to the high level of reproducibility between the older and 2017 observation images, we compared change in individual bolsters. Selected jpeg files of individual bolster images were edited in Adobe Photoshop Lightroom® (2015.10 Release) to remove background colour by reducing all HSL (Hue, Saturation and Luminance) channels other than green to the –100 level. Colour removal was undertaken on all individual bolster images except for plate 1, (left image, 2017) and plate 5 (left image, 2017) as it was difficult to differentiate between cushion species and coloniser species using this technique on that image. The aspect ratio of the images was as-shot out of camera with a 4 x 3 horizontal to vertical aspect ratio. Twelve vertical and 16 horizontal grid lines were superimposed over each image. To estimate the proportion of each image occupied by the whole bolster area, total cover was measured for each grid cell with any bolster cover at either date. Cushion species cover, coloniser species cover and dead or absent vegetation were expressed as a proportion of the total area of these cells.

RESULTS

In the image from Lake Mackenzie in 2016, a cushion heath occupies the foreground and middle ground (pl. 1). The cushion heath is mostly unburned; however, the perimeter was subject to intense scorching and desiccation and displays a moderate to heavy degree of erosion. A segment of a cushion in the lower right quarter of the image was more severely burned. Large areas of soil are exposed by burning around this cushion. The cushion mosaic is interspersed with *Poa* spp., *Baloskion australe* (R.Br.) B.G. Briggs & L.A.S. Johnson and a single *Richea scoparia* Hook.f. shrub. The dominant cushion species is *A. forsteroides* with patches of *P. lawrencei*.

By 2017, the heavily burned areas between and outside the cushions were mostly recolonised by grass and herb species; however, areas of bare soil still remain (pl. 1). The perimeter of the unburned cushion has evidence of erosion. The segment of cushion more severely burned in the 2016 image was necrotic. Most of the biomass within the cushion heath remains and appears predominantly undisturbed. Numerous patches of *Empodisma minus* (Hook.f.) L.A.S. Johnson & D.F. Cutler and *Poa* species are present within the bolster matrix.

A pair of Poatina images capture an area spanning less than 5 x 5 m with approximately 30% of the scene occupied by a shallow bare depression (pl. 2). In the 2013 image the depression is full of water. Cushions are the dominant lifeform. The dominant cushion species is *A. forsteroides* with patches of *P. lawrencei*. The dead remains of woody shrubs are present, as well as live grasses and herbs, including *Astelia alpina* R.Br., *B. australe*, *Rytidosperma pauciflorum* (R.Br.) H.E. Connor & E. Edgar and *Poa* species. Charred areas of exposed earth provide evidence of recent burning. Desiccated and fresh macropod droppings are visible. The fire had the greatest impact between the more elevated cushion bolsters. Burning of cushion plants is evident along their margins.

By 2017, the scene is dominated by grasses, especially in areas that were more heavily fire-affected in the 2013 image. While bolsters appear to be in good condition, they have been colonised by monocotyledons. These include all species identified in the 2013 image, with the addition of *Deyeuxia quadriseta* (Labill.) Benth. and *Lepidosperma filiforme* Labill.. *E. minus* is common. Monocotyledons do not appear to be heavily grazed as evidenced by intact inflorescences. No woody shrub regrowth is evident.

A second pair of Poatina images captures an area spanning less than 5 x 5 m with approximately 10% of

TABLE 1 — Site and image metrics for Lake Mackenzie, Poatina and Walls of Jerusalem site

Location	GPS coordinate GDA94/55G	Direction of photograph (°)	Fire start date	Fire end date	Fire span (days)	Photo 1	Photo 2	Time between (days)
Lake MacKenzie	0449231 5386577	311	19-Jan-16	4-May-16	106	27-Jan-16	29-Mar-17	427
Poatina (1)	0487322 5361824	45	29-Nov-12	6-Jan-13	38	9-Apr-13	5-Mar-17	1426
Poatina (2)	0487310 5361810	45	29-Nov-12	6-Jan-13	38	9-Apr-13	5-Mar-17	1426
Poatina (3)	0487321 5361816	45	29-Nov-12	6-Jan-13	38	9-Apr-13	5-Mar-17	1426
Walls of Jerusalem	0441906 5369459	39	3-Jan-13	3-Jan-13	1	22-Feb-13	2-Apr-17	1500

PLATE 1 — Looking towards Lake McKenzie. Left: 27 January 2016 (Jayne Balmer), Right: 29 March 2017 (Morgan Harding).

PLATE 2 — Poatina Road 1. Left: 9 April 2013 (Jamie Kirkpatrick), Right: 5 March 2017 (Jamie Kirkpatrick).

the scene occupied by a shallow depression (pl. 3). In 2013, cushions were the dominant recognisable lifeform. The dominant cushion species is *A. forsteroides*. There is an absence of taller lifeforms. There are dead stems of woody plants. Monocotyledons, including *A. alpina*, *L. filiforme* and *Poa* occur among bolsters, charred areas and exposed soil. Desiccated and fresh macropod droppings are visible. Burning of cushion plants appears to have been restricted to the margins of the bolsters.

By 2017, the overall scene was dominated by monocotyledons, especially in areas that were more severely burned in 2013. The cushions were heavily colonised, particularly by *E. minus*. There were few macropod scats. Woody shrubs began to recover from the impact of burning.

Another pair of Poatina images depicts a single bolster spanning less than 3 x 3 m (pl. 4). In 2013, roots protruded from two edges of the *A. forsteroides* bolster. The bolster edges appear eroded, exposed and desiccated. Much of the cover of the bolster appears scorched. A light scatter of short monocotyledons and herbs is evident on the exposed soil. *E. minus* and *L. filiforme* were the only two monocotyledon species present within the bolster matrix. *Euchiton traversii* (Hook.f.) Holub. and an unidentified species were the only herbs. Beyond the eroded area in which the bolster is located, monocotyledons are dominant.

By 2017, grass and herb cover was higher than in 2013 in the immediate proximity of the cushion. Once-exposed edges of the bolster were no longer visible due to colonisation of *E. minus*, *B. australe*, *Dichelachne* spp. and *Rytidosperma pauciflorum*. *Euchiton traversii* persisted from 2013. The cushion displayed a high degree of secondary species colonisation.

The Walls of Jerusalem cushion images display a scene of approximately 2 x 2 m (pl. 5). In 2013, the area surrounding the two *A. forsteroides* bolsters consists of approximately 30% burned and exposed roots and soil, and 70% short grasses. The bolster surface was scorched, although some green shoots of *A. forsteroides* are evident. *Hydrocotyles sibthorpioide* Lam., *Lycopodium fastigiatum* R.Br. and *Oreomyrrhis ciliata* Hook.f. grow on the bolster surface. The area separating the two cushion bolsters was occupied by *Poa*. The upper centre of the larger bolster appears dead. By 2017, the bolsters had recovered, apart from a new necrotic lesion between the two cushions. *Gaultheria tasmanica* (Hook.f.) D.J. Middleton joined the colonisers of 2013.

PLATE 3 — Poatina Road 2. Left: 9 April 2013 (Jamie Kirkpatrick), Right: 5 March 2017 (Jamie Kirkpatrick).

PLATE 4 — Poatina Road 3. Left: 9 April 2013 (Jamie Kirkpatrick), Right: 5 March 2017 (Jamie Kirkpatrick).

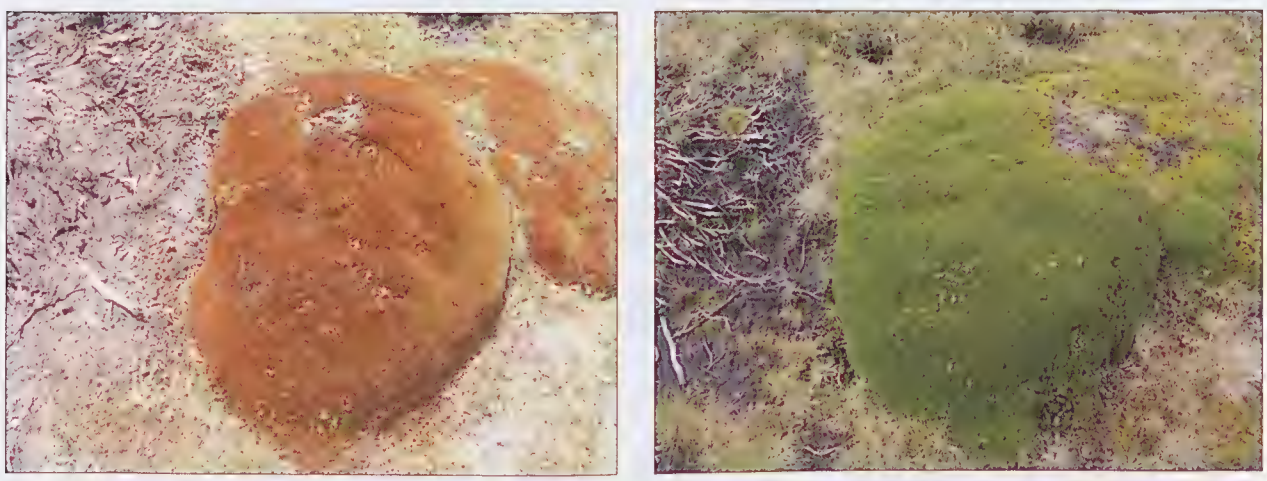

PLATE 5 — Walls of Jerusalem. Left: 22 February 2013 (Jamie Kirkpatrick), Right: 2 April 2017 (Morgan Harding).

Greater richness of coloniser species was observed on bolsters in all five 2017 observation images than on the earlier images (table 2). *Empodisma minus* was identified in burned areas in most 2017 images but not in earlier images. *Deyeuxia quadriseta* was only visible in Poatina 2017 images. Where *Astelia alpina* was present, it was identified at both times. *Poa* spp. were present in paired images at all places. *Coronidium scorpioides* was identified at Poatina where it was observed in both paired images. *Hydrocotyle sibthorpioide*, *Lycopodium fastigiatum* and *Oreomyrrhis ciliata* were only identified at the Walls of Jerusalem, where they were observed in both images.

Coloniser species richness was greater in 2017 than earlier (table 2). There was a natural logarithmic increase in species richness from time of burn (fig. 1). Bare ground decreased, as cushion cover increased at greater than twice the rate of other cover (fig. 2).

DISCUSSION

The rapid recovery of *Rytidosperma pauciflorum*, *Deyeuxia quadriseta*, *Empodisma minus*, *Astelia alpina* and *Poa* spp. is consistent with decadal changes after fire in both cushion-dominated vegetation and alpine heathland (Kirkpatrick & Dickinson 1984, Kirkpatrick *et al.* 2010). The rhizomatous habit of *E. minus* makes it particularly likely to evince a rapid recovery, while the hemicryptophyte life form of other grasses facilitates survival and regeneration where fire does not penetrate the surface. The resistance and resilience of *Abrotanella forsteroides* in the early years after fire is also consistent with the results of decadal scale observations (Kirkpatrick & Dickinson 1984). The resilience of cushion species following complete surface scorching has been previously noted (Kirkpatrick & Dickinson 1984, Kirkpatrick 1997, Kirkpatrick *et al.* 2010). It is a function of below surface buds in non-shrubby cushion species

TABLE 2 —Taxa observed on surfaces of bolster in Plates 1–5

Coloniser species	Walls of Jerusalem		Poatina (1)		Poatina (2)		Poatina (3)		Lake Mackenzie	
	2013	2017	2013	2017	2013	2017	2013	2017	2016	2017
Astelia alpina			•	•	•	•				
Baloskion australe			•	•		•		•		•
Coronidium scorpioides			•	•						
Rytidosperma pauciflorum			•			•		•		
Deschampsia cespitosa										•
Deyeuxia quadriseta				•		•				
Dichelachne spp.								•		
Empodisma minus				•		•		•		•
Erigeron pappocromus										•
Euchiton traversii			•			•	•	•		
Gaultheria tasmanica		•								
Hydrocotyle sibthorpioides	•	•								
Lepidosperma filiforme				•	•	•	•			
Lycopodium fastigiatum	•	•								
Oreomyrrhis ciliata	•	•								
Poa sp.	•	•	•	•	•	•			•	•
Poranthera microphylla						•				
Unidentified herb	•						•			
Species Richness	4	5	6	7	3	9	3	5	1	5

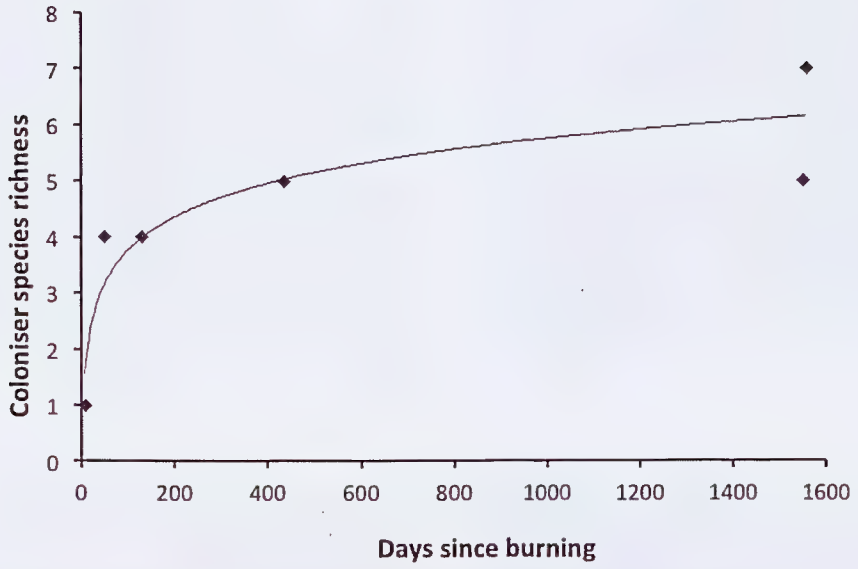

FIG. 1 — Mean richness of coloniser species in cushions for Lake Mackenzie, Poatina and Walls of Jerusalem sites by time since burning. y = 0.871ln(x) – 0.257, R2 = 0.842.t

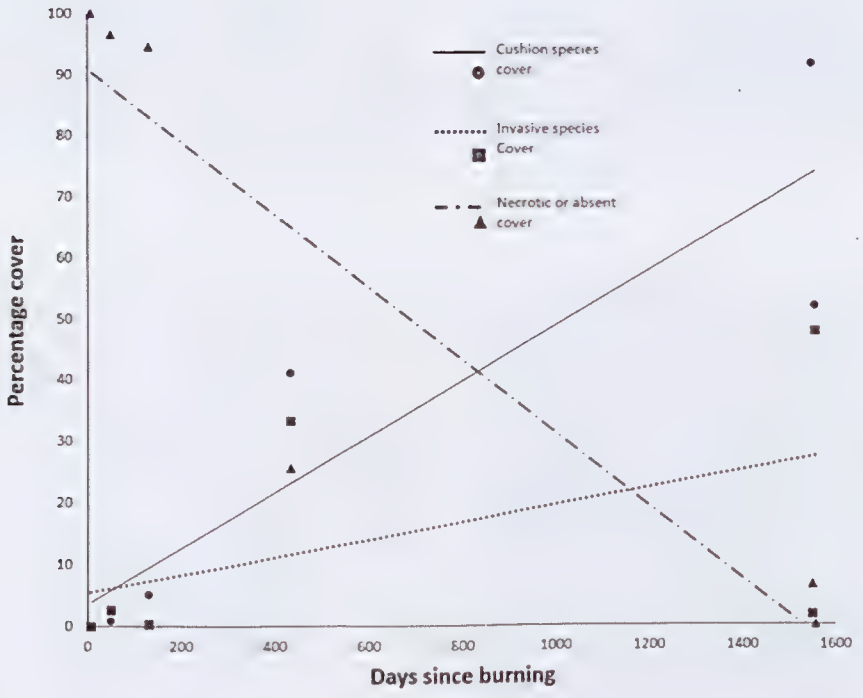

FIG. 2 — Temporal change in cushion plant cover, coloniser species cover and necrotic or absent vegetation cover on cushions.

facilitating rapid vegetative regeneration (Kirkpatrick 1997).

Localised necrosis of a single cushion segment at Lake Mackenzie that was subject to combustion rather than scorching suggested an exception to post-fire resilience of cushions as understood in the literature. Vegetation growing around, between or within bolsters including, but not limited to, coloniser species appears to be able to generate enough heat during a fire to kill subsurface cushion plant buds. Severe and persistent effects of fire are suggested to have a greater impact on Tasmanian alpine vegetation than climatic changes (Kirkpatrick *et al.* 2010). It may be that cushions will benefit from low frequency and intensity fire through the opportunity to expand into areas previously dominated by shrubs (Kirkpatrick *et al.* 2010), as is indicated by our observations. However, in the overall context of alpine ecology such fires are undesirable.

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(accepted 4 September 2018)

RESIDUAL PRESENCE AND IMPACT ASSESSMENT OF HERBICIDE FOR GORSE CONTROL AT LONG POINT RESERVE, TASMANIA, AUSTRALIA

by L. Williams and D. Kingdom

(with one text-figure)

Williams, L. & Kingdom, D. 2018 (14:xii): Residual presence and impact of herbicide for gorse control on native species diversity at Long Point Reserve, Tasmania, Australia. *Papers and Proceedings of the Royal Society of Tasmania* 152: 17–19. ISSN: 0080–4703. Tasmanian Land Conservancy, Taroona, Tasmania 7005, Australia (LW*, DK) *Author for correspondence. Email: laura.williams20@gmail.com

Gorse (*Ulex europaeus*) is an invasive weed managed extensively throughout temperate areas of the world. At Long Point Reserve on the east coast of Tasmania, management has been highly effective, reducing the cover of the gorse population by 90% using cut-and-paint applications of glyphosate and spot-spraying of GrazonTM Extra. Considerable quantities of Grazon™ Extra have been applied repeatedly over a 10-year period and there is concern over whether the herbicide is persisting in the soil and impacting native plant recruitment. We collected soil samples and quantified plant species richness across sites with a range of spray frequencies. No herbicide residues were detected in the soil and plant species richness did not differ between treated and untreated areas. Given the moderate persistence of the active ingredients of GrazonTM Extra (picloram and triclopyr), detection in the soil was expected; however, it appears these herbicides have either quickly dissipated, leached to other areas or the skill of the spray contractor resulted in little spray drift or excess herbicide application. This research suggests good practice chemical control of gorse does not negatively affect native species, although this may be situation-specific.
Key Words: picloram, triclopyr, *Ulex europaeus*, herbicide, weed control.

INTRODUCTION

Gorse (*Ulex europaeus* L.) is a Weed of National Significance in Australia, infesting up to one million hectares across Australia (Gouldthorpe 2006). It causes reduced stocking rates, presents a fire hazard, provides habitat for feral animals and can form dense monocultures in natural areas, reducing floral diversity (DPIPWE 2014). In Tasmania, gorse is distributed across much of the state, infesting between 30 000 and 100 000 hectares (Gouldthorpe 2006). Methods for the control of gorse include mechanical clearing, cultivation, herbicide application, hand-weeding, fire, grazing, pasture management, revegetation and biological control. A combination of several methods is often most effective (Gouldthorpe 2006).

The management of invasive species can result in many benefits to the ecosystem, but can sometimes result in unexpected negative outcomes (Caut *et al.* 2009, Rinella *et al.* 2009). For example, removal of invasive plants can trigger reinvasion by the target species, or other invaders or hinder the establishment of native species (see Kettenring & Adams 2011). The off-target impacts of invasive plant control or eradication are rarely considered in scientific studies (Kettenring & Adams 2011), though potential impacts are considered in management manuals like the Weeds of National Significance manuals.

The Tasmanian Land Conservancy (TLC) has been controlling gorse at Long Point Reserve on the east coast of Tasmania for the past decade. An integrated weed control program utilising cut-and-paint techniques with glyphosate, spot-spraying with Grazon™ Extra (picloram and triclopyr) and burning has resulted in a 90% reduction in the cover of gorse. Although control is highly successful, large quantities of herbicide have been repeatedly applied to the reserve and so concerns have arisen as to whether this is negatively impacting on native plant diversity. We aimed to determine the residual presence of herbicides following gorse control by quantifying the concentration of picloram and triclopyr in the soil at Long Point in areas with differing spray frequencies and to assess the impact of any herbicide residue on native plants by measuring the native species diversity in areas of differing spray frequencies.

METHODS

Long Point Reserve is owned and managed by the not-for-profit conservation organisation, TLC. It is located at Moulting Lagoon on Tasmania's east coast (42.0506°S, 148.1512°E). The reserve comprises 386.5 ha of mixed saltmarsh/woodland/grassland overlying sandy soils (TLC 2008). Moulting Lagoon is an internationally important wetland site (Ramsar) (TLC 2008). Long Point has a long history of human activity leading to some environmental degradation including the introduction of weeds.

When Long Point was purchased by TLC in 2005, there were significant gorse infestations covering 49.9 ha, with much of this area being a gorse monoculture. The previous owners burnt gorse which reduced the biomass in the short term but did not prevent spread and establishment. The gorse spider mite (*Tetranychus lintearius* Dufour, 1832) biological control agent is established at Long Point, but its effectiveness is unknown. The TLC has reduced the gorse cover by 90% using combinations of cutting and painting individual plants with glyphosate, spot-spraying denser areas with Grazon™ Extra and burning.

Sample collection and analysis

On 25 October 2016 we collected soil samples at Long Point to test for herbicide residue and measured plant species richness at four sites: high spray frequency (sprayed five times between 2005 and 2016); low/moderate spray frequency (sprayed three times between 2008 and 2016); unsprayed/low spray frequency (sprayed once or twice between 2005 and 2016) and an unsprayed low-lying area downslope of sprayed areas potentially subject to herbicide leaching. Due to concern arising over herbicide impacts well after herbicide application, we had to design our sampling methodology around treatments that had already been established and so could not avoid the pseudoreplication that resulted from our sampling methods. It is unlikely that each of the sites is different, but we recognise that applying one treatment at each of the sites, rather than all treatments at all sites is not optimal design.

Within each site, fifteen 1 m x 0.5 m quadrats (arrayed along three randomly assigned transect lines) were established. Within each quadrat the presence of dead gorse, gorse seedlings and each vascular plant species was recorded. Within each site, three soil samples were collected, one at the start of each transect, using a square tree planting device (5 x 5 cm x 15 cm deep). The surface litter layer was removed from each soil sample to enable analytical analysis and the remainder of each sample stored in a glass jar and refrigerated prior to analysis. The top 15 cm of the soil was collected as this is where we considered the herbicides most likely to accumulate and affect subsequent seedling emergence. The soils were sent to a NATA accredited laboratory (Eurofins, Melbourne) where the soil samples were tested for residues of triclopyr using the method MGT 530A and picloram using the method LTM-ORG-2180 Phenoxy Acid Herbicides. These tests are based on SW-846 Test Method 8000D: Determining Chromatographic Separations from the United States Environmental Protection Agency. The reporting limit was 0.5 mg/kg.

In 2006, prior to widespread spraying, 5 x 50 m-long transects (line intercepts) were established to study vegetation composition. Any plant intersecting the transect was recorded in the categories of bracken, gorse, grass, forb, native shrub or sedge. Two of the transects in a high spray frequency area close to our sample collection sites were resurveyed in 2016, with flooding preventing access to the remaining three transects.

Statistical analysis

Statistical analysis was carried out using R version 3.2.1. Species richness within the quadrats was analysed using analysis of variance (ANOVA) where P values were considered significant when < 0.05.

RESULTS

With the exception of a single sample, no picloram or triclopyr was detected in any of the 12 soil samples above the limit of reporting value of 0.5 mg/kg. One sample had the limit of reporting raised to < 2 mg/kg of triclopyr due to matrix interference (i.e., where another parameter in the soil interfered with the reliability of the testing method).

The average plant species richness in quadrats at Long Point in 2016 was 5 (± 1 sd) in the high spray frequency, 6 in both the low/moderate (± 2 sd) and no/low (± 3 sd) spray frequency areas and 7 (± 1 sd) in the unsprayed area. There was no statistically significant difference in species richness between the sites of different spray frequency ($P = 0.09$)

The transect data could not be statistically analysed due to the small number of replicates, but the data do show some trends (fig. 1). In both transects, the cover of gorse declined considerably between 2006 and 2016. The abundance of grasses also declined, while bracken and sedges increased. Forbs and native shrubs showed partially contrasting trends.

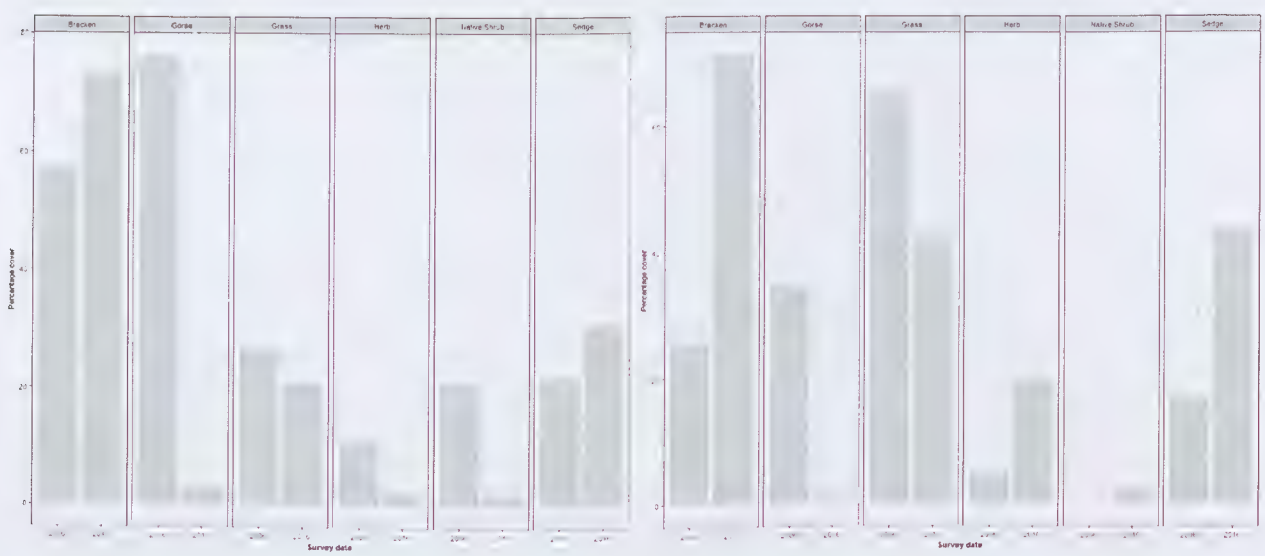

FIG 1. — Percentage cover of vegetation classes in Transect 1 (left) and Transect 2 (right) at Long Point Reserve in 2006 prior to widespread application of Grazon™ Extra and in 2016 following 10 years of herbicide application

DISCUSSION

None of the twelve soil samples collected from Long Point contained residues of picloram or triclopyr, despite multiple applications over a decade. Given we sampled across sites with a range of spray frequencies and application times (the most recent March 2016) and collected samples from directly under gorse plants sprayed six months earlier, it is surprising no herbicide residues were present.

Picloram is reported to have a half-life of between one month and three years, with a typical half-life in field studies of 20–49 days. Triclopyr is less persistent with half-lives of 4–314 days and 7–54 days in field studies (Tu *et al.* 2001, Lewis *et al.* 2016). The dissipation of both compounds is highly dependent on soil and environmental conditions (Tu *et al.* 2001, Lewis *et al.* 2016). Given the range of half-lives, it is possible picloram and triclopyr had mostly dissipated from the soil prior to sample collection. Triclopyr, and particularly picloram, are both subject to leaching, particularly in sandy soils such as at Long Point (Tu *et al.* 2001). We did not detect any herbicide residues in the area directly down slope of the heavily sprayed area, indicating leaching may not be occurring, however more research is required to determine whether the herbicide residues are leaching to deeper soil depths or off-site.

Another possibility for the lack of herbicide residues in the soil is that very little herbicide is reaching the soil surface. The spray contractor used is a highly skilled operator, taking care to avoid spray drift or excess herbicide application. Given we collected some samples directly under recently sprayed gorse plants and still did not detect any herbicide residues, this appears to be a likely scenario.

Our results indicate that the application of Grazon™ Extra has not resulted in reduced species diversity in areas of different spray frequency at Long Point Reserve. Trends in the line transect data suggest that while there has been a decline in gorse since widespread spraying at the site, there has been no consistent decline in any plant form. This is surprising given that picloram and triclopyr are both used to control a variety of woody plants and herbs (Tu *et al.* 2001) and so would be expected to kill native shrubs and herbs as well as gorse. Likewise this may be attributed to the skill of the spray contractor in avoiding non-target plants.

This research suggested that Grazon™ Extra carefully and selectively applied at Long Point Reserve, even in dense infestations, with repeat applications over extended time periods, does not persist in the surface soil at, or directly down slope of, the spray site. However, we were constrained by resources which limited the number of soil samples collected and the way in which treatments were applied which created pseudoreplication. Further research is required to determine whether herbicide residues have remained in the litter layer (which was removed for analysis), leached to deeper soils or if long-distance dispersal and movement into the water table has occurred. Species diversity did not differ between unsprayed sites and sites of varying spray frequencies. It is important to note that herbicide persistence is highly dependent on soil and environmental properties and so this result may not be extrapolated to all areas. However, this is a very important finding which requires further research to determine whether concerns over off-target impacts of gorse control are founded.

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CORRECTING MISCONCEPTIONS ABOUT THE NAMES APPLIED TO TASMANIA'S GIANT FRESHWATER CRAYFISH *ASTACOPSIS GOULDI* (DECAPODA: PARASTACIDAE)

by Terrence D. Mulhern

(with three plates)

Mulhern, T.D. 2018 (14:xii) Correcting misconceptions about the names applied to Tasmania's Giant Freshwater Crayfish *Astacopsis gouldi* (Decapoda:Parastacidae). *Papers and Proceedings of the Royal Society of Tasmania* 152: 21–26. ISSN 0080–4703. Department of Biochemistry and Molecular Biology, School of Biomedical Sciences, The University of Melbourne, Vic 3010, Australia. Email: tmulhern@unimelb.edu.au

Tasmania is home to around 35 species of freshwater crayfish, all but three of which are endemic. Among the endemic freshwater crayfish, there are three large stream-dwelling species: the Giant Freshwater Crayfish, *Astacopsis gouldi* – the world's largest freshwater invertebrate, the medium-sized *A. tricornis* and smaller *A. franklinii*. Errors and confusion surrounding the appropriate Aboriginal names for these species, and the origin and history of the scientific name of *Astacopsis gouldi* are outlined.

Key Words: Tasmanian freshwater crayfish, giant freshwater lobster, Giant Freshwater Crayfish, *Astacopsis gouldi* Aboriginal words, lutaralipina, tayatitja, scientific names, William Buelow Gould, Charles Gould.

INTRODUCTION

Tasmania is home to three species of large stream-dwelling freshwater crayfish assigned to the endemic genus *Astacopsis*. Of these three species, *Astacopsis gouldi* Clark, 1936, known commonly as the Giant Freshwater Crayfish, or 'lobster', is the world's largest freshwater invertebrate. *A. gouldi* is found in northern Tasmania and the medium-sized *A. tricornis* Clark, 1936 and smaller *A. franklinii* (Gray, 1845) are found in southern Tasmania, in the west and east, respectively (Richardson *et al.* 2006). In the period since they were first described by European naturalists, there have been several revisions of the nomenclature for these animals. Here, the history of the naming and classification of these species is outlined, from the pre-colonial period, through to the current era of molecular genetics. The appropriate assignment of Aboriginal names is discussed to address past and ongoing misattribution. This is followed by a résumé of the confusion surrounding the etymology of the specific name given to the Giant Freshwater Crayfish, in the context of the history of the nomenclature and classification of the three species. Finally, the misconceptions surrounding the origin of the epithet *gouldi* are addressed.

TASMANIAN ABORIGINAL NAMES FOR FRESHWATER CRAYFISH

Freshwater crayfish were eaten by Tasmanian Aborigines (Roth 1899, Noetling 1910, Hiatt 1967, Plomley 2008). The word list of Tasmanian Aboriginal languages compiled by Brian Plomley contains two different words for these animals (Plomley 1976, p. 262). The first is 'tate.yer' for which Plomley lists two variant transliterations taken from G.A. Robinson's notes from the 1830s: 'tate.yer' from the eastern Oyster Bay tribe; and 'tate.te' from the Bruny Island tribe in the far south. Plomley also lists a further two variants from Joseph Milligan's later vocabulary: 'tayatea' (Oyster Bay) and 'tay-a-teh' (Bruny Island/South) (Milligan 1859). It is important to note that these were English transliterations of Aboriginal words, as heard by the recorders, none of whom were trained linguists, and interpretation of the significance of differences requires linguistic analysis. Plomley also listed another, quite different, word describing freshwater crayfish: 'loe.ter.er.le.pe.en.ne' (Plomley 1976, p. 262). This word was recorded by G. A. Robinson in the 1830s from the Cape Portland tribe of the northeast. Plomley suggested that this word refers to:

> *"...a northern one which grows to a large size, sometimes as long as sixty centimetres, and is known as the Freshwater Lobster..."* (Plomley 1976, p. 262),

by which he means what is now known as *A. gouldi*. Considering the geographic distributions of these animals (Richardson *et al.* 2006), we can be almost certain that 'tate.yer' and its variants refer to the smallest of the three species, *A. franklinii*, as this is the only member of the genus found in southeastern Tasmania. Whether 'loe.ter.er.le.pe.en.ne' refers exclusively to the Giant Freshwater Crayfish *A. gouldi* is less certain, as the Cape Portland tribal region includes areas where *A. gouldi* and *A. franklinii* are found separately, as well as the narrow strip where their distributions overlap. Sadly, no western language group words were recorded for freshwater crayfish, so no Aboriginal name is available for *A. tricornis*.

In recent times it has been common to use 'tayatea' as the Aboriginal name for *A. gouldi* (Threatened Species Section 2006, Richardson 2008, Shepherd *et al.* 2011, Reynolds *et al.* 2013, Anon 2017). While recognition of Aboriginal natural history knowledge is appropriate and to be encouraged, the historical record does not support the use of this word for this species. Furthermore, the misattribution of 'tayatea' extends beyond the genus

Astacopsis. *Engaeus tayatea* Horwitz, 1990, a burrowing crayfish found in the northeast of Tasmania, was named with the following explanation: "The specific epithet was taken from the aboriginal word for 'freshwater lobster' (Plomley 1976)" (Horwitz 1990 p. 605).

The palawa kani Language Program of the Tasmanian Aboriginal Centre has revived 'lutaralipina' (pronounced: lu-tar-rah-lee-pee-nah) as the appropriate Tasmanian Aboriginal term for the Giant Freshwater Crayfish (*A. gouldi*); and 'tayatitja' (pronounced: tie-yah-tee-tchah) for the small Southern Freshwater Crayfish (*A. franklinii*). Palawa kani is the only Aboriginal language now spoken in lutruwita (Tasmania) and its alphabet is linguistically designed to represent the original sounds of Aboriginal words that were recorded by Europeans (Tasmanian Aboriginal Centre 2018).

HISTORICAL OVERVIEW OF *ASTACOPSIS* NOMENCLATURE

The early European explorers and settlers ate freshwater crayfish (Gould 1870, Crawford *et al.* 1962, Plomley 2008), but it was not until the middle of the nineteenth century that the first scientific study of Tasmanian freshwater crayfish was published (Gray 1845). John Edward Gray in his 'Descriptions of some new Australian animals' included "The Van Diemen's Land Cray-fish. *Astacus Franklinii*" (Gray 1845, p. 409). He named the animal after Sir John Franklin, the famed Arctic explorer and lieutenant-governor of Van Diemen's Land from 1837–1843, who, together with his wife Lady Jane Franklin (née Guillemard), were great patrons of science and the arts in the new colony. Surprisingly, despite the striking difference in adult size between the giant freshwater 'lobster' and the smaller southern crayfish, all Tasmanian stream-dwelling freshwater crayfish were still classified as a single species under the name *Astacus/Astacopsis franklinii* until the turn of the twentieth century.

A first attempt to differentiate between the northern and southern stream-dwelling freshwater crayfish was made in 1908–09. The English naturalist Geoffrey Smith, Fellow of New College Oxford, spent six months in the austral spring and summer of 1907–08 travelling around Tasmania and making observations of the flora and fauna. He described these observations in his book *A Naturalist in Tasmania* (Smith 1909) and in a contemporaneous paper, specifically on freshwater crustaceans, in the *Transactions of the Linnean Society of London* (Smith 1908). In *A Naturalist in Tasmania*, Smith describes being taken fishing near Bridport in northeastern Tasmania and catching and eating a large freshwater crayfish:

> *"This Crayfish is the largest in the world, and is quite a distinct species from the small Crayfish which is found in the creeks of the southern part of the island, and which never grows to more than five or six inches."* (Smith 1909, p. 110)

In both publications he referred to the large northern crayfish as *A. franklinii*. In the *Transactions* paper he described the smaller southern crayfish as *A. tasmanicus* (Smith 1908, p. 70) following the work of the German naturalist Wilhelm Ferdinand Erichson (1846). Perhaps Smith could not read German, because it is quite clear from the details of its habits as described by Erichson, and related to him by his local collector Adolphus Schayer, an employee of the Van Diemen's Land Company, that Erichson's *A. tasmanicus* was a burrowing crayfish, rather than a stream-dwelling species. Smith published again a few years later, seeming to wrestle with whether or not his misnamed *A. tasmanicus* was indeed a separate species, or simply a smaller variant of *A. franklinii*:

> *"In the highland streams of the south and centre a small form occurs (var.* tasmanicus*) which may or may not be reckoned as a separate species".* (Smith 1912, p. 149)

In 1936 Ellen Clark published a comprehensive revision of stream-dwelling and land crayfish of Australia (Clark 1936). Clark reclassified the burrowing crayfish *Astacus tasmanicus* Erichson, 1846 as *Parastacoides tasmanicus* Clark, 1936 when she erected that genus. Clark, an otherwise excellent taxonomist, unfortunately never saw the type species that Schayer collected and passed on to Erichson. If she had, she would not have used "*tasmanicus*" as one of her species names in *Parastacoides*, because the specimen is actually a species of *Geocharax*, no doubt collected from northwest Tasmania, where Schayer was active (Richardson 2017). Clark also split *Astacopsis franklinii*, erecting *Astacopsis gouldi* and *Astacopsis tricornis*, for the northern and western forms, respectively and restricting the name *A. franklinii* to the southern forms (Clark 1936). However, further changes followed. In mid-twentieth century Riek (1969) published another Tasmanian species, *Astacopsis fluviatilis*. Subsequently, *A. fluviatilis* and *A. tricornis* were synonymised with *A. franklinii* (Swain *et al.* 1982). A decade later, Premek Hamr's (1992) revision reinstated *A. tricornis* as a valid species – thus restoring the situation defined by Clark more than half a century earlier. Hamr sampled very widely across Tasmania and was able to make a detailed assessment of certain key morphological features (e.g., width of and number of ridges on the rostrum at the front of the head) and the significant differences in the average size of adults. Subsequently, the genetic distinctiveness of these three species was confirmed by biochemical analysis at the close of the twentieth century (Avery & Austin 1997). In recent years, direct analysis of genetic differences by mitochondrial genome sequencing has supported these earlier morphological and biochemical studies (Sinclair *et al.* 2011, Gan *et al.* 2017).

ONGOING NAMING CONFUSION

Gray's 1845 sketch of the giant crayfish (pl. 1) was always somewhat hidden from the public eye, due to it being published in an Appendix to the journals describing Edward John Eyre's exploration of central mainland Australia (Eyre 1845). However, in recent time it is an earlier artistic rendering of one of these animals that has captured the public imagination. This image is an exquisite watercolour called the 'Freshwater Crayfish' (pl. 2) by the celebrated

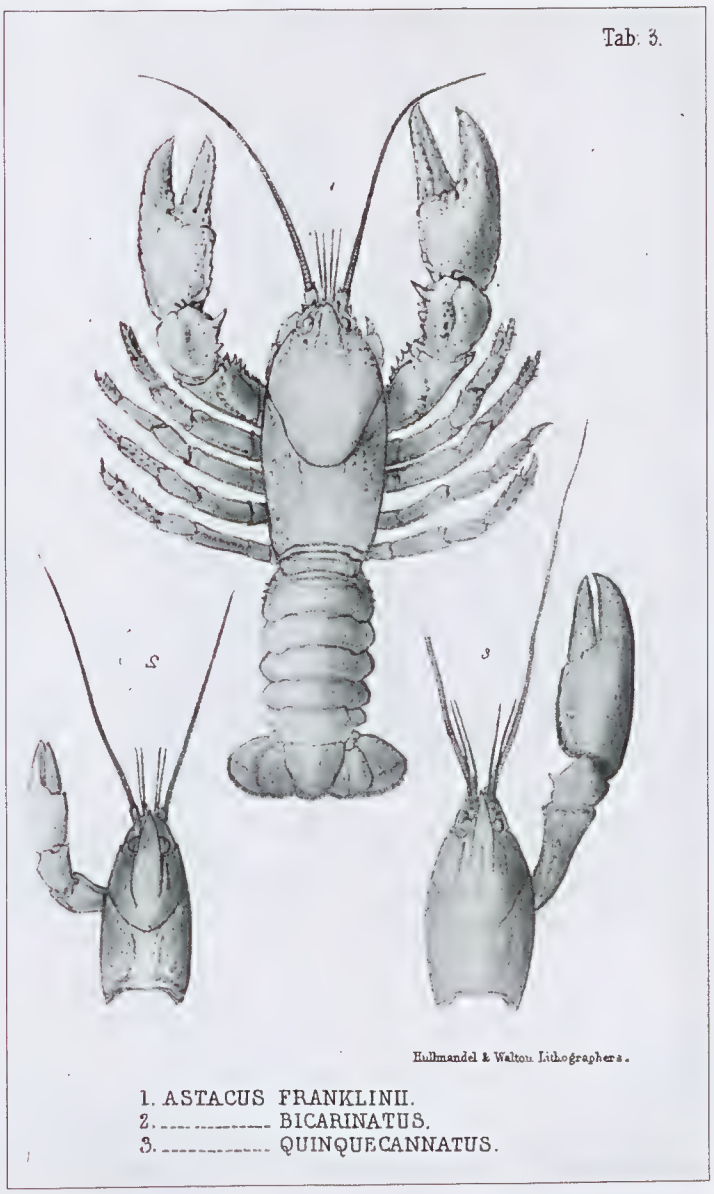

PLATE 1 — Sketches of Australian freshwater crayfish. From John Edward Gray's *Description of Some New Australian Animals* (Gray 1845), which appeared as an appendix to Edward John Eyre's *Journals of Expeditions of Discovery into Central Australia and Overland from Adelaide to King George's Sound* (Eyre 1845). The main image is described as The Van Diemen's Land Cray-fish. *Astacus Franklinii* [possibly *Astacopsis gouldi*]. The lower right partial image is: The Western Australia Cray-fish. *Astacus quique-carinatus* [now known as *Cherax quinquecarinatus*]; and lower left partial image is: The Port Essington Cray-fish. *Astacus bicarinatus* [now known as *Cherax bicarinatus*].

PLATE 2 — The 'Freshwater Crayfish' (most likely *Astacopsis tricornis*) in Gould's *Sketchbook of Fishes* (Gould c. 1832). Watercolour on paper by Willian Buelow Gould, painted at Macquarie Harbour. [Reproduced with the permission of the Allport Library and Museum of Fine Arts, Tasmanian Archive and Heritage Office.]

convict artist William Buelow Gould (c.1832). However, two tenacious misconceptions have developed around this painting. Firstly, it is widely believed that the painting is of the Giant Freshwater Crayfish *A. gouldi* – it is not. The painting is almost certainly the western species, *A. tricornis*. Secondly, because of the first misconception, it is common to believe that *A. gouldi* was named after the artist Gould – it was not. The scientific name of the Giant Freshwater Crayfish was chosen by Clark (1936) to honour the geological surveyor Charles Gould (1834–1893).

William Buelow Gould (c. 1832) (pl. 3) painted the 'Freshwater Crayfish' at Macquarie Harbour. Gould, whose real name was Holland, was a painter of ceramics who was transported in 1827 for theft. He was an alcoholic and this led to further offences in Van Diemen's Land: he was sentenced to secondary punishment, twice at Macquarie Harbor, and later at Port Arthur. On Sarah Island in Macquarie Harbour his artistic talents ameliorated the conditions of his imprisonment, as he was assigned as house servant to the settlement's medical officer, Dr William de Little, and painted natural history specimens for the doctor (Meade 1959, Allport 1966). W.B. Gould's (c. 1832) *Sketchbook of Fishes* comprises 36 images of aquatic fauna from around Macquarie Harbour. It is held in The Allport Library and Museum of Fine Arts in Hobart. It is considered Gould's finest work and has been recognised as a national treasure (National Library of Australia 2007). Gould's sketchbook inspired Richard Flanagan's (2001) humorous and fantastical novel *Gould's Book of Fish: A Novel in Twelve Fish*. The freshwater crayfish features in chapter 10, where Flanagan's protagonist, the escaped convict Billy Gould, encounters a newly moulted freshwater crayfish on a rock by an alpine tarn.

The misconception, that Gould's painting depicts *A. gouldi*, was popularised in Robert Hughes' book on Australia's convict period *The Fatal Shore* (Hughes 1987) and has since been perpetuated widely (Richardson 2008, Tasmanian Museum and Art Gallery 2013, Anon. 2017). The second misconception, that *A. gouldi* must have been named after William Buelow Gould has also become prominent (Hughes 1987, Tasmanian Museum and Art Gallery 2013, Anon. 2017). Although any documentation associated with de Little's collection has not survived, based on morphological detail evident in the painting and the most likely geographical location of its collection (the lower reaches of the Gordon River), it was noted by Hamr (1992) that the painting is most probably of *A. tricornis*. Whether by accident or design, Flanagan's fictional encounter between Billy Gould and the freshwater crayfish also supports the correct identification. By placing it in an alpine environment, Flanagan immediately marks it as *A. tricornis*, as *A. gouldi* is found only at low altitudes.

In terms of the basis of the naming of *A. gouldi* by Ellen Clark (1936), she neither mentioned the artist W.B. Gould nor the painting 'Freshwater Crayfish', but rather highlighted the many pertinent observations on the giant freshwater 'lobster's' distribution, diet and habits made by the government geologist, Charles Gould. Like many scientists of his day, Charles Gould ventured beyond his specialisation, and he published 'On the Distribution and Habits of the Large Fresh-Water Crayfish (*Astacus* Sp) of the Northern Rivers of Tasmania' in the *Monthly Notices of Papers and Proceedings of the Royal Society of Tasmania* (Gould 1870). In his paper, Gould noted that:

> *"I am not aware that this has been specifically described by naturalists, although its unusually large size, abundance in certain localities, estimation as a delicacy for the table, added to its facility of capture and observation should long since have acquired for it that attention at their hands."* (Gould 1870, p. 42)

CONCLUSIONS

Linguistic research and the revival of Tasmanian Aboriginal language have provided clarity on the appropriate Aboriginal terms ascribed to *Astacopsis gouldi* and *Astacopsis franklinii*. Hopefully, future interrogation of historical sources will reveal an Aboriginal name for *Astacopsis tricornis*. Unsurprisingly, the romantic notion of a giant freshwater 'lobster' being named after a convict artist, who painted a delicate and nuanced watercolour of it while incarcerated in a convict hellhole is common. Sadly, these are both misconceptions – the painting was almost certainly a different species and the 'lobster' *Astacopsis gouldi* was not named for the artist William Buelow Gould; it was named in honour of the government geological surveyor and field naturalist, Charles Gould.

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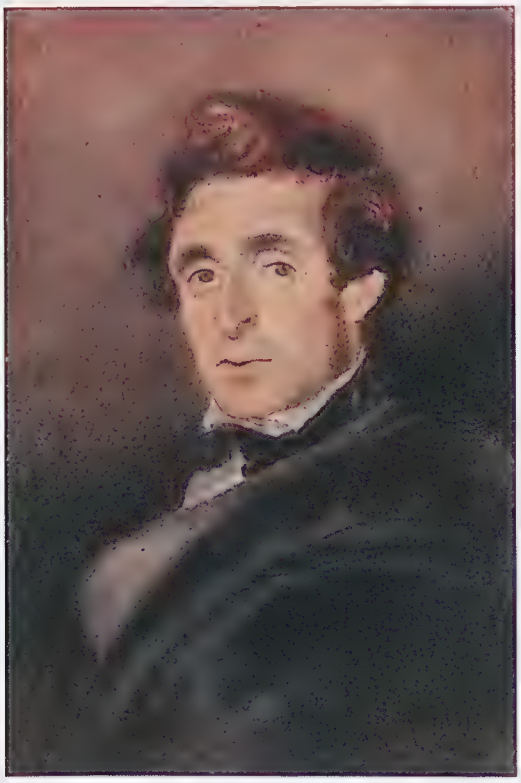

PLATE 3 —William Buelow Gould (1801–1853) and Charles Gould (1834–1893). Left: Portrait of William Buelow Gould c. 1840 by Thomas Bock [Reproduced with the permission of the Tasmanian Museum and Art Gallery]. Right: Photograph of Charles Gould by Charles Alfred Wooley, from the Allport Album XII. [Reproduced with the permission of the Allport Library and Museum of Fine Arts, Tasmanian Archive and Heritage Office.]

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IMPACT OF CHANGES IN LIGHTNING FIRE INCIDENCE ON THE VALUES OF THE TASMANIAN WILDERNESS WORLD HERITAGE AREA

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(with two text-figures)

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The Tasmanian Wilderness World Heritage Area has ecosystems and cultural landscapes that have been created and/or influenced by the interactions between the physical environment, the biological environment, fire regimes and people. Lightning is the dominant cause of fire in the 2010s, yet was rarely recorded as a cause of fire before 1980, when arsonists caused most fires. The main potential impact of this change in primary cause of fire incidence on the values of the Tasmanian Wilderness World Heritage Area is the loss of ecosystems dominated by highly fire-sensitive palaeoendemics, organosols and Aboriginal cultural landscapes. At the same time as these values are threatened, a lack of burning threatens some fire-dependent vegetation types. We suggest an increase in planned burning of fire-tolerant and fire-requiring vegetation, maintenance of ignition suppression, an improvement in rapid response capability and an improvement in rapid detection of lightning fires is required in order to maintain many world heritage values.
Key Words: Tasmanian Wilderness World Heritage Area, lightning fire, management, Tasmania.

INTRODUCTION

The Tasmanian Wilderness World Heritage Area (TWWHA), managed by the Parks and Wildlife Service, has been listed by UNESCO for its globally significant natural and cultural values (Australian Government 2016). The TWWHA is home to globally significant biodiversity and geodiversity, contains areas of globally significant Aboriginal cultural heritage as well as encompassing areas of great natural beauty (TWWHA Management Plan 2016). The globally significant palaeoendemic plants of the TWWHA are concentrated in places where fire has been rare or absent (Jordan *et al.* 2016). In contrast, about a quarter of the TWWHA's vegetation is moorland, typically on nutrient-poor soils, which is dependent on frequent fire in order to maintain its species and structural diversity (Balmer & Storey 2010). Interactions between fire, vegetation and topography have moulded the spatial patterns of most of the globally significant ecosystems of the TWWHA (Jackson 1968).

Fire has been part of the landscape and ecology of the TWWHA for many millennia. People have used fire for management in the region for at least 35 000 years (Kee *et al.* 1993, Cosgrove 1995, Allen 1996, Bowdler 2010) and, at most, 70 000 years (Jackson 1999). Aboriginal people were likely to have deliberately burned buttongrass moorlands and grasslands. Infrequent fires in scrub and eucalypt forest and the very few fires that occurred in rainforest, subalpine and alpine areas were likely to have been the results of natural ignition and/or escapes (Marsden-Smedley 1998, Johnson & Marsden-Smedley 2002, Marsden-Smedley & Kirkpatrick 2000). The available evidence suggests that while most fires prior to the British invasion of Tasmania were probably small- to medium-sized (< 1000 ha), large fires did burn parts of the present TWWHA, at a frequency of approximately once in 250 years (J. Marsden-Smedley unpublished data).

Following the forced removal of Aboriginal people from the region, the fire regime changed to a pattern of fewer small-scale fires and more frequent extensive fires. During the 1930s, two extensive fires burned much of the TWWHA, but since 1939 no extensive fires in the TWWHA have occurred (Marsden-Smedley 1998, Johnson & Marsden-Smedley 2002), although there have been a few medium-sized fires such as the ecologically devastating 1960/61 Central Plateau fire and the large but ecologically benign 2012/13 Giblin River fire (Parks and Wildlife Service unpublished fire history database).

The cause of fires in the TWWHA has changed over the decades from predominately human-ignited to predominately lightning-ignited. Before 1980, Bowman & Jackson (1981) estimated that lightning fires were only responsible for about 0.1% of fires and about 0.01% of the area burned. Since circa 2000, lightning has become the main ignition source of fires in the TWWHA (Parks and Wildlife Service unpublished fire history database, figs 1, 2). An increase in lightning ignitions has also been recorded in the alpine mountains of mainland Australia as well as globally (Zylstra 2018).

The increase in lightning-ignited fires could result in the return to extensive fires, such as those seen in the 1890s and 1930s. Lightning fires pose a particular threat to the TWWHA as they are more likely than human-ignited fires to occur in remote areas, making suppression more difficult (Flannigan & Wotton 1991). In addition, lightning storms often result in numerous ignitions across the landscape, overwhelming the suppressive capacity of the fire management agencies (Flannigan *et al.* 2009).

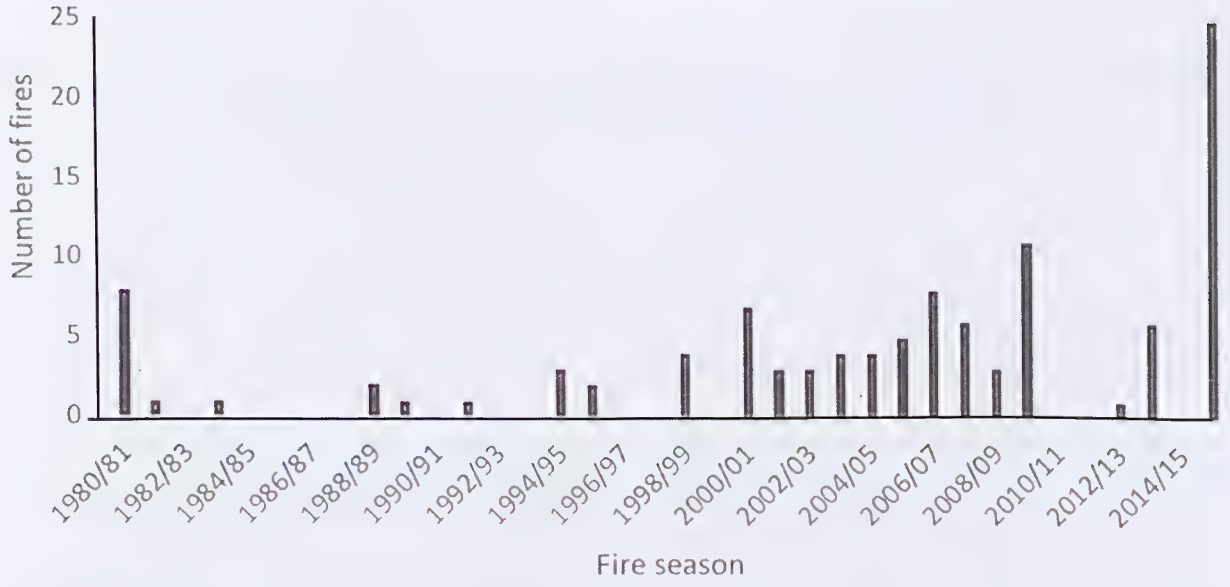

FIG. 1 — Number of fires each fire season, 1980/81–2015/16.

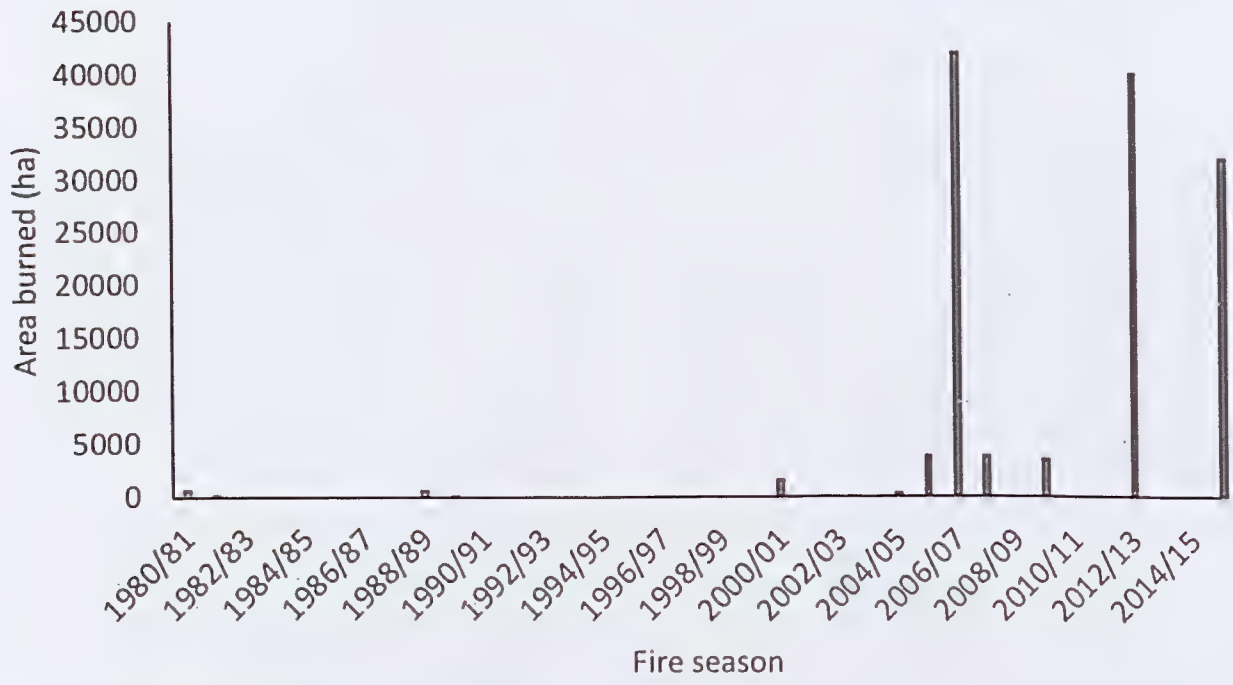

FIG. 2 — Area burned in each fire season, 1980/81–2015/16.

In the present paper, we review the potential impact of increased lightning fires on world heritage and other natural values in the TWWHA, and discuss management approaches to mitigate this threat.

POTENTIAL IMPACTS OF CHANGES IN LIGHTNING FIRE ON NATURAL VALUES

The major adverse impacts predicted from increases in fires are on the Gondwanan rainforest and alpine communities (particularly those containing endemic coniferous and/or deciduous species) from which fire has been long absent (Jordan *et al.* 2016). The main species of concern are the native conifers, King Billy Pine (*Athrotaxis selaginoides* D. Don), Pencil Pine (*Athrotaxis cupressoides* D. Don), Huon Pine (*Lagarostrobos franklinii* (Hook.f.) Quinn), Diselma (*Diselma archeri* Hook.f.), and the dwarf pines *Microcachrys tetragona* (Hook.) Hook.f. and *Pherosphaera hookeriana* W. Archer, along with Deciduous Beech (*Nothofagus gunnii* (Hook.f.) Oerst). These clades have no capacity to vegetatively recover when foliage is fully burned, do not store disseminules in their canopies or soil, and mostly have poor seed dispersal. This means that if burned by even a single fire, these species

are typically rendered locally extinct for extended time periods (e.g., in excess of 500 to 1000 years; Kirkpatrick & Dickinson 1984, Brown 1988, Peterson 1990; Robertson & Duncan 1991, Kirkpatrick *et al.* 2010).

Of secondary concern are adverse fire impacts to organosols, *Sphagnum* peatlands, and eucalypt forests. Organosols and peatlands have the potential to be degraded by fire, especially if fires occur under conditions when their peat soils are dry enough to sustain subterranean burning; in some cases for periods of weeks or months after the initial ignition. Fires will also degrade (Hill 1982, Hill & Read 1984, Read 2005) and potentially eliminate (di Folco & Kirkpatrick 2013) rainforests. In addition, very frequent fires have the potential to destroy eucalypt forests, especially where the eucalypts rely on seed regeneration (Bowman *et al.* 2014).

The organic soils of the TWWHA are continuous over oligotrophic parts of the landscape, ranging from typically shallow (i.e., 0.1–0.3 metres depth) black muck peats under moorland to red mor organosols under rainforest (di Folco 2007). The moorland organic soils most at risk from climate change and lightning fires are those with high organic contents, which most commonly occur in gullies and flat sites (di Folco 2007). Under previous climatic conditions, these organosols would have been protected from burning by having high moisture contents, but if the predicted increased dryness resulting from climate change occurs (Department of Premier and Cabinet 2012) then they will have the potential to be degraded by large-scale peat fires. The diverse alpine organic soils (Kirkpatrick *et al.* 2014) can be truncated by fire. Their recovery takes decades to centuries (Kirkpatrick & Dickinson 1984, Bridle & Kirkpatrick 1997). In wet scrub communities, the accumulation of organic material in the duff and fibric layers of the soil can be rapid with tens of centimetres accumulating within 60 years (di Folco & Kirkpatrick 2013). However, there may be catastrophic losses of these duff and fibric layers during and immediately following fires due to their highly flammable nature and subsequent erosion through aeolian and fluvial processes on exposed surfaces.

The *Eucalyptus regnans* F. Muell. tall eucalypt forests are the globally outstanding example of the hot fire paradox, eliminated if there are two hot fires within a 10–30 year time period (Ashton 1976, Balmer *et al.* 2004) or if the interval between fires exceeds the circa 500 year eucalypt lifespan (Wood *et al.* 2010). Most of these forest types in the TWWHA are dominated by mature and/or old growth eucalypts, although there are also many forests with a range of tree ages, the product of incomplete mortality following lower intensity ground fires (Turner *et al.* 2009). If there are closely repeated landscape-scale catastrophic fires, such as those in 1898 and 1934 in Tasmania, the remaining *E. regnans* forests might meet the fate of some of the *E. delegatensis* R.T. Baker ssp. *delegatensis* forests in Victoria on the mainland of Australia, where there are extensive areas in which the eucalypts have become locally extinct following very extensive fires in 2003, 2007 and 2009 (Bowman *et al.* 2014).

Almost all of the TWWHA which is below the climatic treeline is climatically capable of supporting rainforest, even extremely poorly-drained sites (Kirkpatrick 1977, 1984). In the absence of fire, tree and shrub species that require large gaps or disturbed ground for regeneration would be confined to river banks, places where landslips were frequent (Cullen 1991) and rocky subalpine areas (Kirkpatrick & Balmer 1991). Thus, fire is important in allowing the persistence of many species and communities in the TWWHA. Values that could be lost with a reduction in fire include Aboriginal cultural landscapes, along with the main fire-dependent vegetation formations of eucalypt forest, wet scrub, grassland and buttongrass moorland (Jackson 1968).

Despite the general undesirability of fire in the alpine zone, some alpine daisy shrubs, which are wind-dispersed and short-lived, can become highly abundant after fire, dying out after approximately half a century (Kirkpatrick *et al.* 2002). In long unburned areas they are only able to persist in areas where fluvial erosion provides a constant regeneration niche. Additionally, fire may be construed to have positive conservation effects on cushion plants in the alpine and subalpine parts of the TWWHA, in places where rushes, sedges and shrubs overwhelm cushion plants (Harding & Kirkpatrick 2018). Where all the species in the cushion mosaic are able to recover rapidly after a fire, in contrast to the invading shrubs, fire may have a positive conservation effect on TWWHA values. However, in the central and western mountains, the frequent presence of the fire-sensitive cushion plant *Dracophyllum minimum* F. Muell. (Kirkpatrick & Dickinson 1984) in the mosaics makes fire undesirable.

The buttongrass (*Gymnoschoenus sphaerocephalus* Hook.f.) moorlands are a globally distinct ecosystem of high universal value (Balmer *et al.* 2004), characterised by flammability at globally high moisture levels (Marsden-Smedley & Catchpole 1995) and being able to survive at globally low phosphorus contents (Jackson 1977). Depending on their topographic position and geologic fertility, an absence of fire for 20–100 years will see the species-rich moorland become species-poor wet scrub and eventually rainforest after 250–500 years (Jarman *et al.* 1988). The invertebrate fauna of the moorland, some of which (such as *Allanaspides*) are ancient, rapidly recover from fire (Driessen *et al.* 2013, Driessen & Kirkpatrick 2017), although *Acarina* might be an exception (Green 2010). Moorland is critical habitat for two rare parrots, which prefer recently burned (i.e., Orange-bellied Parrots *Neophema chrysogaster* Latham, 1790) or less recently burned (i.e., Ground Parrots *Pezoporus wallicus* (Kerr, 1792)) moorlands (Driessen 2010).

Finally, a fire frequency which eliminates or reduces shrubs whilst promoting more highly palatable grasses and forbs will benefit world heritage values by maintaining enhanced numbers of native herbivores which will in turn support enhanced numbers of marsupial carnivores (Kirkpatrick *et al.* 2011, Styger *et al.* 2011).

MANAGEMENT RESPONSES

The consequences of changing patterns of ignitions on TWWHA values depend upon the rapidity of the fire suppression response, with suppression only possible during a brief temporal window post-ignition, after which efforts can only be concentrated on containment.

If the drier summers that are predicted to occur in western Tasmania with climate change (Department of Premier and Cabinet 2012, Love *et al.* 2016) occur, and are associated with a continuation of dry lightning ignitions, then the probability of rainforest burning will probably be greater than has been the case in the past. However, if an increased frequency of ignition occurs when rainforest soils are wet, therefore burning only moorland, the burned moorland could provide a barrier to the movement of fire into rainforest, lowering the probability of rainforest loss. Planned aerial ignition of large areas of moorland when the rainforest is too moist to burn will achieve the same outcome (Marsden-Smedley & Kirkpatrick 2000, King 2004, King *et al.* 2006). Rainforests are highly unlikely to sustain burning if there has been more than 50 mm of precipitation in the previous month, irrespective of the daily fire danger rating (Styger & Kirkpatrick 2015).

The very large increase in lightning fires in the past 45 years (Parks and Wildlife Service unpublished fire history database), in association with predicted increases in vegetation and soil dryness resulting from climate change, indicates that the option of relying on inherent ecosystem resilience is highly unlikely to result in the maintenance of TWWHA values. The most probable outcome of such a regime of benign neglect (Brown 1996) is high-level adverse impacts on many of the world heritage listed values of the region.

A better option for the management of the TWWHA is the implementation of a comprehensive regime of planned burning in fire-dependent vegetation types, in association with active fire suppression in fire-sensitive vegetation types. This strategy offers the highest probabilities of achieving the TWWHA's management goals (King *et al.* 2006, 2008, 2013, Department of Primary Industries, Parks, Water and Environment 2015, Bentley & Penman 2017). Systems for performing such a fire management regime have already been published and operationally tested (Marsden-Smedley 2009), but have not been implemented in a political context in which protection of built property has been the main goal in planned burning programs for the State as a whole.

Suppression activities should take place as soon as practical after an ignition occurs, when the fire is still small, as this will optimise chances for success. To achieve this rapid response, additional resources for current remote area firefighting and improved lightning detection systems for the TWWHA will be required.

CONCLUSION

The ecosystems of the TWWHA are a highly complex mosaic of states and a cat's cradle of potential transitions, mediated by the region's climate, fire regimes and site productivity. Any change in the incidence and severity of fire is likely to adjust the balance of the states, which vary continuously between each other, but appear to be distinct because of feedbacks between vegetation state and differences in propensity to burn (Jackson 1968, Wood & Bowman 2012, Harris *et al.* 2018). The fire-sensitive palaeoendemics dominate vegetation that has a high degree of stability compared to most other states, but even this vegetation exhibits directional change at the century scale (Kirkpatrick & Bridle 2013). Moorland and grassland on moderately fertile to fertile ground are highly unstable without repeated disturbance by fire, disappearing under shrubs and trees within decades (Balmer & Storey 2010, Bowman *et al.* 2013, Wood *et al.* 2017). Shifts between vegetation types as a result of a change in fire regimes are highly variable in their potential reversibility. This variability relates to the fire adaptations and dispersal capacities of the species present in the previous state and the distance of the area that has experienced a transition from surviving vegetation in the previous state. For example, vegetation that has changed from heathland to scrub may return to a structural heathland after a fire event, but at the cost of the loss of those taxa which do not have a persistent seed store or well dispersed seeds (Bargmann & Kirkpatrick 2015).

In order to protect the formal and informally recognised values of the TWWHA from increased lightning fires, active management is required. We recommend a comprehensive planned burning regime (see King *et al.* 2006) augmented with increased remote area fire suppression capabilities during the fire season. An improved lightning detection system for western Tasmania is also required to identify and suppress lightning fires before they grow to a size at which they are unable to be contained.

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Conflicts of interest

The authors declare no conflicts of interest.

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DISTRIBUTION, HABITAT CHARACTERISTICS AND CONSERVATION STATUS OF *LEPIDIUM HYSSOPIFOLIUM* DESV. (BRASSICACEAE) IN TASMANIA

by Mark Wapstra

(with three text-figures, six plates, one table and one appendix)

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Lepidium hyssopifolium Desv. (Soft Peppercress) is a threatened vascular plant that is widespread in eastern Tasmania. It is virtually restricted to anthropogenic habitats such as disturbed grassy road verges and the drip-zone of mature ornamental conifers, with very few sites in "natural" habitat (presumed to be some form of native grassland and grassy woodland). A review of database and herbarium collections revealed 87 locations for the species in Tasmania, of which 33 are locally extinct, 30 are of uncertain status and 24 are confirmed as extant. Most subpopulations are localised and of low abundance. The species appears to be resilient and robust to most forms of disturbance, although is absent from areas subject to heavy grazing. Removal of overtopping ornamental trees appears to result in local extinction in the longer term. Complex management of sites along road verges is not considered warranted but continuation of some long-term monitoring at a limited number of sites and active in situ management to minimise risk of heavy disturbance or destruction during road works is appropriate. A review of the formal conservation status of the species suggests that a status of vulnerable under the Tasmanian *Threatened Species Protection Act 1995* may be appropriate but that more detailed population information is recommended before a change of status from endangered is made.

Key Words: *Lepidium hyssopifolium*, Brassicaceae, threatened, endangered, vulnerable, distribution, habitat, conservation, Tasmania.

INTRODUCTION

Lepidium hyssopifolium Desv. is presently listed as endangered under both the Tasmanian *Threatened Species Protection Act 1995* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. In Tasmania, the species has long been considered a "weedy native" (e.g., Kirkpatrick & Gilfedder 1998) because for several decades it appears to have become restricted mainly to anthropogenic habitats.

Most populations occur on road verges, usually associated with mature ornamental pine trees, leading to some speculation that the species may be naturalised rather than native (Wapstra 2018). However, in the absence of unequivocal evidence for its naturalised versus native status, the species remains listed as endangered and should be managed as such.

This paper is the culmination of an extensive examination of database records and herbarium collections undertaken as part of a statewide review of the populations of *L. hyssopifolium* in Tasmania. The combination of desktop review and field assessments has provided the opportunity to update the published information on the distribution, habitat characteristics and conservation management of the species.

METHODS

Database and collection review

Three sources of records of *L. hyssopifolium* were interrogated and reviewed to produce a complete list of all known locations of the species in Tasmania. Data from all three sources were used to collate a table of collections/records of *L. hyssopifolium* from Tasmania. All information considered relevant (such as notes on collection sheets and database records regarding habitat, abundance and extent) was transferred to the table.

Tasmanian Herbarium (Tasmanian Museum & Art Gallery) (HO)

The collection database was interrogated for all collections of *Lepidium* and this was used to systematically examine every specimen of the genus held at this institute. The main reason all specimens of *Lepidium* were examined was to ensure that any collections of other species previously misidentified were also considered (for the record, this resulted in one additional specimen of *L. pseudotasmanicum* Thell. being re-determined as *L. hyssopifolium*).

Every specimen was examined microscopically to confirm its identity as *L. hyssopifolium*. In some cases, a confirmation slip was added to the collection sheet. This was mainly undertaken for the specimens previously determined as *L. tasmanicum*, a taxon not currently accepted by the Tasmanian Herbarium and recognised as a nomenclatural synonym of *L. hyssopifolium* (de Salas & Baker 2017). Most of the specimens held at HO had previous "det. slips" from people considered as experts in the Brassicaceae and the genus (e.g., H. Hewson, N. Scarlett).

DPIPWE's *Natural Values Atlas* database (NVA)

The *Natural Values Atlas* (NVA) is the Tasmanian government's repository of natural values data, managed by the Tasmanian Department of Primary Industries, Parks, Water & Environment. The database includes records of flora listed as threatened under the Tasmanian *Threatened Species Protection Act 1995* and/or the Commonwealth *Environment*

Protection and Biodiversity Conservation Act 1999. The database incorporates most of the data from the Tasmanian Herbarium through a formal data exchange agreement.

Any records in the NVA that are not supported by a voucher at a recognised institute (such as HO) need to be treated with caution. While there is a vetting process for data input into the NVA, this is undertaken by DPIPWE staff who can only utilise the available information to make a reasonable decision on inclusion of the supplied data. While for many species this is not an issue (e.g., highly distinctive species), for a species such as *L. hyssopifolium*, with its attendant (historical) identification issues and the requirement for some level of familiarity and expertise by the observer in its identification, any unvouchered records need to be considered carefully on a case-by-case merit basis.

The Observations Search function of the online database was used to access all records of *L. hyssopifolium*. All data fields were included in the exported output.

Atlas of Living Australia (ALA)

The *Atlas of Living Australia* (ALA) is an e-infrastructure that is funded by the Australian Government via its National Collaborative Research Infrastructure Strategy (NCRIS). It is a collaborative partnership of organisations that have stewardship of biological data and expertise in biodiversity informatics, including museums, biological collections, community groups, research organisations, government (State and Commonwealth) and natural resource managers.

The ALA includes data of threatened flora from DPIPWE's NVA and collection information from the Tasmanian Herbarium. It also includes collection information from other Australian herbaria.

The online species search function was used to access all records of *L. hyssopifolium* from the Tasmanian region, with all available fields downloaded as a .csv file.

Field survey

Field surveys focused on sites under the jurisdiction of the Department of State Growth because the primary aim of the project was to determine the status of previously reported sites to determine if any were suitable for longer term conservation management. However, the surveys were extended to as many of the previously reported sites as possible, with only a limited number on some private properties not assessed (appendix 1 indicates the locations where field surveys were undertaken).

Prior to the field survey, the known locations of *L. hyssopifolium* were reviewed and transferred to field maps showing topography, cadaster and other features as necessary to maximise the chance of detecting the species in the field from the available information. These maps and hand-held GPS (Garmin Oregon 650) were used to navigate to the location of the known site. Surveys radiated out (or extended linearly along a road verge) from the known site.

Where *L. hyssopifolium* was detected, abundance was estimated by direct counts using the waypoint function on the GPS (in most cases) or by estimates (where the species was locally abundant and counting individuals was not practical). The site supporting (or not supporting) the species was described (e.g., vegetation type, geology, disturbance history).

Voucher specimens were collected under DPIPWE permits TFL 15280 and 17029 (in the name of Mark Wapstra), where such voucher material was not already held at HO and where sufficient material was available for such a collection (some sites with only a low number of plants were not sampled).

Lepidium hyssopifolium was identified in the field by examination of the scapes using a hand-lens (species is characterised by a short grey pubescence). Some material needed to be re-examined by microscope in the laboratory due to loss of most hairs (this occurs with older plants).

RESULTS AND DISCUSSION

Distribution

Lepidium hyssopifolium (pl. 1) is widely distributed in eastern Australia, occurring in Tasmania, Victoria, South Australia and New South Wales, and also extends to New Zealand, where it is considered naturalised (Webb *et al.* 1988).

Within Tasmania, the species is widespread in the eastern half of the State (fig. 1). It occurs in the South East, Northern Midlands, Ben Lomond, and Flinders bioregions (appendix 1), and the Flinders, Break O'Day, Northern Midlands, Southern Midlands, Glamorgan-Spring Bay, Central Highlands, Derwent Valley, Brighton, Sorell, City of Glenorchy, City of Clarence and City of Hobart municipalities (appendix 1).

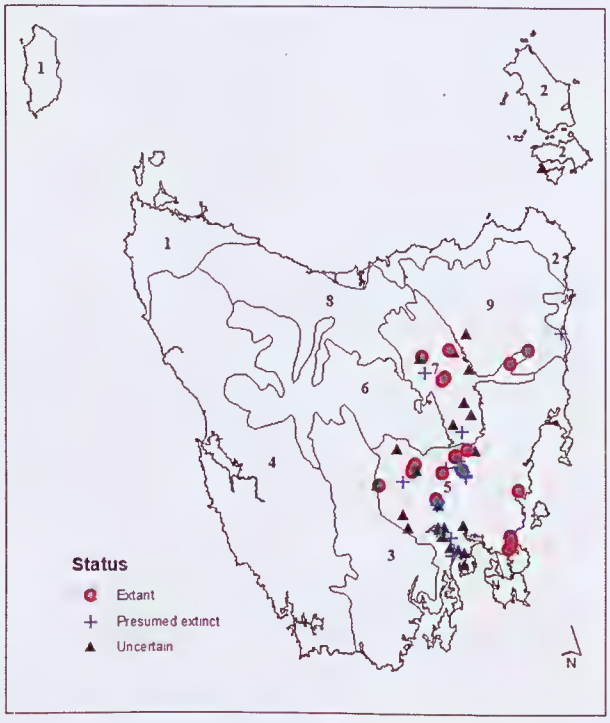

FIG. 1 — Distribution of *Lepidium hyssopifolium* in Tasmania, showing bioregional boundaries. 1. King; 2. Furneaux; 3. Southern Ranges; 4. West; 5. South East; 6. Central Highlands; 7. Northern Midlands; 8. Northern Slopes; 9. Ben Lomond.

PLATE 1 — (A) *Lepidium hyssopifolium* growing in situ amongst needles of *Pinus radiata* (Maclaines Creek, Triabunna, 10 Oct. 2014). (B) Inflorescence and upper leaves showing soft grey pubescence that characterises the species.

Collecting history

There are two early collections of *L. hyssopifolium* from Tasmania. One is by Archer but this collection is undated and bears no detailed locality information (simply labelled "Tasmania"). His dated collections (NVA – 17 April 2017) include just 42 records, with most from 1848 (18 collections) and 1851 (19 collections), and the balance with just one collection each from the years 1840, 1841, 1862, 1863 and 1877. His collections are from a wide area but are focused on his places of residence at 'Woolmers' near Longford (Stillwell 1969) and possibly his more frequent travel routes. Nevertheless, this is still evidence of early colonial collection records.

There is also a collection by Gunn, which is the allocated type of *L. tasmanicum* Thell. (a nomenclatural synonym of *L. hyssopifolium*) held at the Berlin Herbarium (image of collection cited online at http://ww2.bgbm.org/Herbarium). However, this collection is also undated and simply labelled "Hab. Tasmania". The collection probably pre-dates Archer's because most of Gunn's collections are from the 1830s and 1840s (Buchanan 1988). The mention by Curtis and Morris (1975, p. 39) of "material collected by R. C. Gunn at Penquite, Launceston" almost certainly refers to the collection held at Berlin (N. Scarlett pers. comm.).

Chronologically, the next collection is by Maiden in 1918, which is labelled "The Ouse". This record is in the ALA but not the NVA so has hitherto escaped consideration at a state level. The next collection is from 1931 (Ralphs Bay, South Arm). Of some note is that the following collection of *L. hyssopifolium* is from 1974 (Bagdad), a gap of 44 years, which is followed by two collections in 1976 (Preservation Island and Richmond) and one in 1978 (Bridgewater causeway). The next collection is from 1981 (Ross), after which the collections become regular, with only 1983, 1985, 1987, 1988, 1989, 1997, 2000, 2005 and 2013 missing collections (fig. 2).

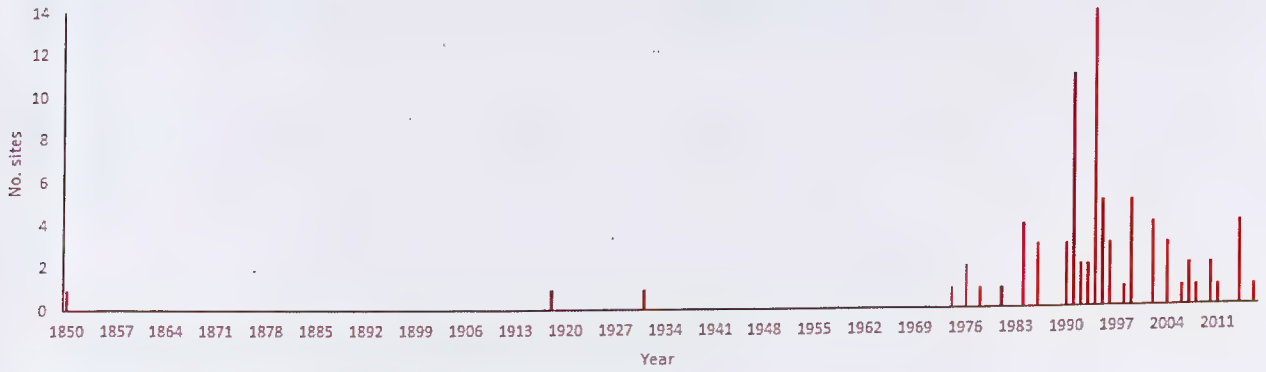

FIG. 2 — Number of sites of *Lepidium hyssopifolium* added in each year.

PLATE 2 — Examples of the typical anthropogenic habitat of *Lepidium hyssopifolium* in Tasmania. (A) Nile Road (frequently slashed exotic grass under Macrocarpa Pine next to stockyards); (B) Bothwell cemetery (rabbit-grazed and dug historic graveyard with ornamental conifers); (C) Valleyfield-Barton roads junction (recently lopped macrocarpa over slashed exotic grass); (D) Oatlands (mature Macrocarpa Pines over gravel car parks).

TABLE 1 — Status of subpopulations of *Lepidium hyssopifolium* in Tasmania

Status category	No.
Extant	24
voucher available	21
voucher absent	3
Locally extinct	33
voucher available	21
voucher absent	12
Uncertain	30
voucher available	15
voucher absent	15
TOTAL	87

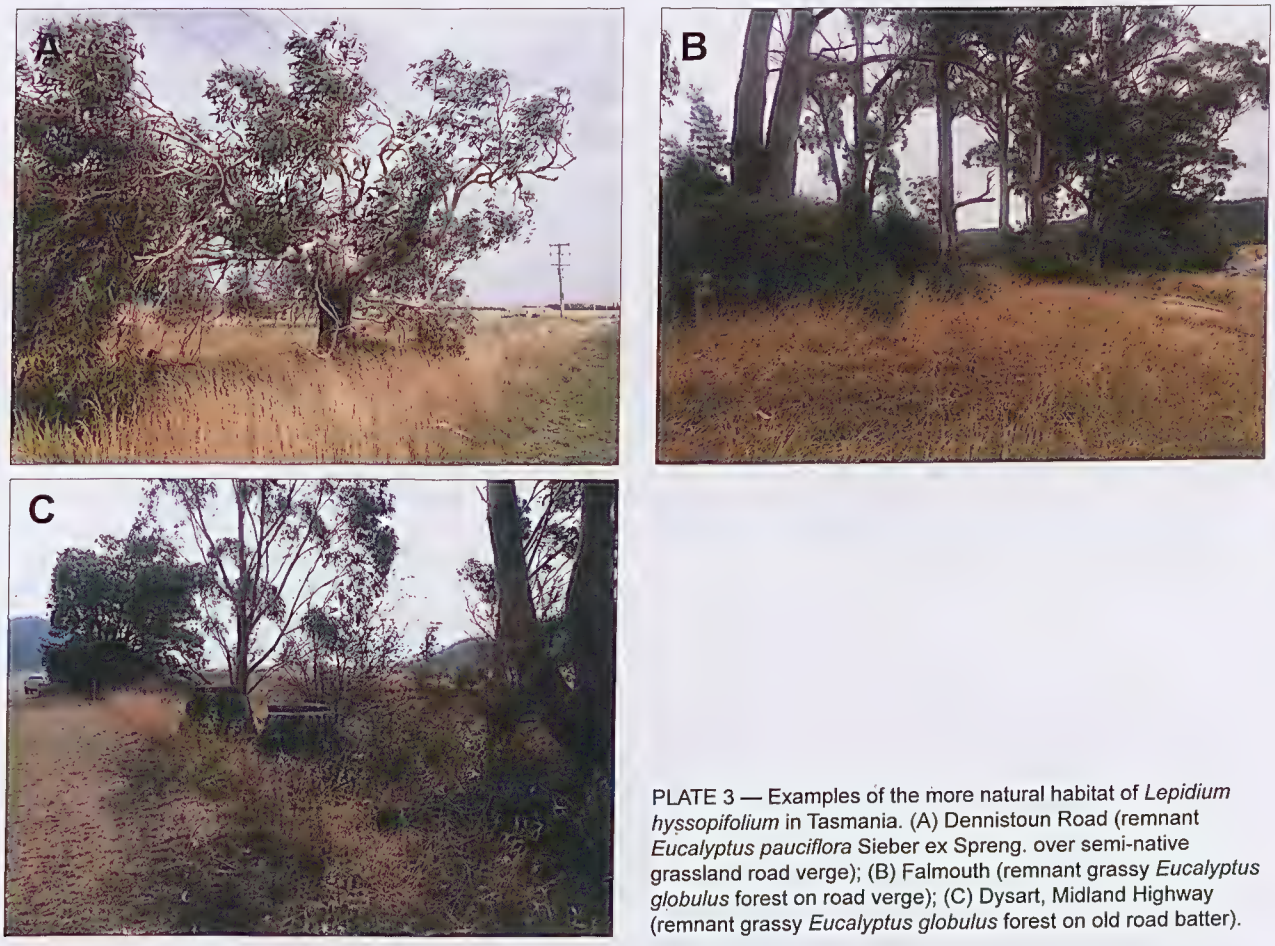

PLATE 3 — Examples of the more natural habitat of *Lepidium hyssopifolium* in Tasmania. (A) Dennistoun Road (remnant *Eucalyptus pauciflora* Sieber ex Spreng. over semi-native grassland road verge); (B) Falmouth (remnant grassy *Eucalyptus globulus* forest on road verge); (C) Dysart, Midland Highway (remnant grassy *Eucalyptus globulus* forest on old road batter).

PLATE 4 — Long-term Roadside Conservation Program (Department of State Growth) site for *Lepidium hyssopifolium* on Esk Main Road near 'Ormley': the species occurs in the drip-zone of the ornamental spruce. Inset: State Growth's Roadside Conservation Site marker for the 'Ormley' site.

PLATE 5 — In situ management of highly localised patch of *Lepidium hyssopifolium* at Fingal Rivulet, where the species occurs amongst sparse grass beneath a mature ornamental *Pinus radiata*.

PLATE 6 — In situ management of highly localised patch of *Lepidium hyssopifolium* on a grassy (weedy) road verge outside Ouse (this is unusual habitat because of the absence of the overtopping mature ornamental conifer).

Habitat characteristics

Most extant subpopulations of *L. hyssopifolium* occur in highly modified anthropogenic habitats (pl. 2). The key habitat features are sandy soils below mature ornamental conifers, usually *Pinus radiata* D.Don (Radiata Pine) and/or *Hesperocyparis macrocarpa* (Hartw. ex Gordon) Bartel (Macrocarpa Pine). Almost all extant sites are on road verges, mainly under local government (council) jurisdiction, with a relatively small number under the jurisdiction of the Department of State Growth.

A limited number of sites is associated with "natural" vegetation (pl. 3). (TSS 2003) indicated that Barker & Johnson (1998) considered the 'Annandale' (private property) at Tunbridge to be especially significant as it is the only relatively natural occurrence of the species. The original collection from this site described the habitat as "*Eucalyptus amygdalina* woodland, growing under trees of *Acacia dealbata*". Kirkpatrick & Gilfedder (1998, p. 468) also regarded this as the site closest to a natural situation for the species, noting: "only one stand, near Tunbridge, has a substantial cover of native plants. Here, *Lepidium* occurs beneath trees in *E. amygdalina* woodland that is very occasionally lightly grazed by sheep". The status of this site is uncertain.

A site along East Bagdad Road was originally from under light *Eucalyptus viminalis* Labill. forest but was on a road verge. A site at Dysart along the old Midland Highway is in highly modified but probably original light eucalypt forest. A site near Falmouth is an interesting "natural" occurrence in that the roadside verge in which the species occurred is a natural (not planted) stand of grassy *Eucalyptus globulus* Labill. forest. The site at the Mount Nelson Signal Station is in similar vegetation. All these sites are now categorised as locally extinct. An extant site at Spring Hill on the Midland Highway also supports the species under *E. globulus* but these are planted trees.

Population parameters

The Scientific Advisory Committee, established under the provisions of the TSPA, produced a set of "*Guidelines for Eligibility for Listing under the* Threatened Species Protection Act 1995" (DPIW 2008). These *Guidelines* include definitions of some key population variables that are used in most measures of conservation status, and these are explored below for *L. hyssopifolium*. These are further explored in the section on the conservation status of the species (table 1).

Number of subpopulations or locations

The analysis has revealed 87 locations of *L. hyssopifolium* recorded from Tasmania (appendix 1). It is noted that some of these locations are quite close to one another (e.g., locations in Fingal, Oatlands and along Tunnack Road). Of concern is that of the 87 sites/subpopulations known, only 24 (28%) are now considered extant (table 1). Most of these are confirmed by a voucher specimen. However, three still do not have a supporting voucher collection, which is concerning for such an historically confused taxon. Of greater concern is that 33 (38%) of the 87 sites/subpopulations are presumed extinct (table 1). Some of these are a small group of sub-sites along Tunnack Road considered as separate sites but possibly all part of one larger meta-population (this hardly changes the conclusion regarding the trends). Of the 87 sites/subpopulations, 30 (35%) are classified as uncertain, most with a supporting voucher. Sites without a voucher cannot be guaranteed to be *L. hyssopifolium* but

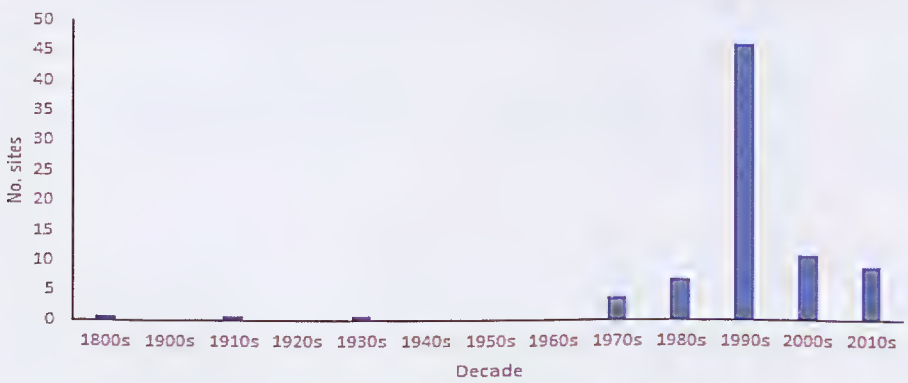

FIG. 3 — Number of sites of *Lepidium hyssopifolium* added in each decade.

are included herein because it is not possible to properly discount the sites. Those with vouchers are listed as uncertain mainly because the population has not been confirmed for over a decade.

The conclusion at this stage is that 24 extant populations of *L. hyssopifolium* can be reliably confirmed in Tasmania, that 30 may be extinct, and 33 have an uncertain status.

It is interesting to examine the historical change in the number of subpopulations of *L. hyssopifolium* in Tasmania (fig. 2). Until the 1970s, there are just four recorded sites for the species. After this time, the records become more frequent, with a high number in the early to mid-1990s. This corresponds to research undertaken by Louise Gilfedder and Jamie Kirkpatrick on the floristics of lowland grassland remnants, and an increase in the number of roadside surveys (as evidenced by records of threatened flora in the *Natural Values Atlas*). Note that very few of the novel sites are the result of re-determinations of collections previously allocated to other species. When this is viewed by decade (fig. 3), the pattern of novel sites is clearer, with most sites added in the 1990s and 2000s.

Extent of occurrence

In the case of *L. hyssopifolium*, it is important to describe how the extent of occurrence was estimated. In the first instance, a minimum convex polygon was created around all populations that can be reasonably considered to be the species. This equates to an extent of occurrence of 19 183 km^2. If only the confirmed extant subpopulations are included, the extent of occurrence is reduced to about 10–11 000 km^2.

If the status of the subpopulation is not taken into account, there has been no major change to the extent of occurrence over time because of the collections at Ouse in 1918, at Ralphs Bay in 1931 and on Preservation Island in 1976, as these three sites provide effective outliers to any minimum convex polygon. That is, while the number of sites has increased (see figs 2, 3), the extent of occurrence has not.

It is difficult to estimate if there has been a change in the extent of occurrence over time because it is not precisely known when subpopulations may have become locally extinct, or the status of many subpopulations. The key measures for the endangered and vulnerable categories under the *Guidelines* are declines of 50% over the last ten years and 20% over the last five years, respectively. As sites such as Nile Road (far north), Maclaines Creek (east), Bream Creek area (southeast), Ouse (southwest) and Bothwell (west) remain extant and have done so for at least the last ten years (based on either the original date of collection and/or an obviously persistent population such as at Nant Lane near Bothwell), there can only have been a minimal reduction in the extent of occurrence over the nominal periods, probably not exceeding the thresholds of 20% or 50%.

Area of occupancy

In the case of *L. hyssopifolium*, it is difficult to estimate the area of occupancy because most records are not accompanied by detailed collection notes. However, most sites appear to be restricted to the growth suppression zone around a few isolated conifers, and such sites generally occupy ca. 10 m^2 – even if 50 of the sites had this area of occupancy, the area occupied equates to about 0.05 ha. Some sites are more extensive. For example, around Oatlands, the species is scattered over ca. 500 m of the fringe of Lake Dulverton and probably occupies 1–2 ha. It is difficult to conclude that *L. hyssopifolium* has an area of occupancy of greater than ca. 5 ha.

A key question under the *Guidelines* is whether there has been a reduction in the area of occupancy (same values as for extent of occurrence are applied i.e., 50% over ten years or 20% over five years, respectively for the endangered and vulnerable categories). It is unlikely that the area of occupancy has changed to meet or exceed these thresholds, simply because some subpopulations with the greater area of occupancy are long-persistent.

Number of mature individuals

Estimating the total statewide abundance of mature individuals for *L. hyssopifolium* is difficult due to the lack of information associated with most records. Where information is available, it can be difficult to separate the number of mature individuals from seedlings. This is a difficult concept with the species anyway because often the flush of seedlings, which can achieve "wheatfield" proportions, can include many smaller fertile plants. Most sites do not appear to have more than 100 mature individuals, and many have much less than this. Some sites, however (e.g., Oatlands, Nile Road, Stewarton Bridge), have locally very high abundance, perhaps in the high 100s to low 1000s of (fertile) individuals. However, even a site such as Stewarton Bridge, which was originally described as a "dense" population (and this is how it appeared in 2017), was only estimated with 47 waypoints (even if each waypoint was up to five plants, the total population is only 235 mature individuals). In my estimate, the statewide population may be in the order of low 1000s but probably does not exceed 10 000 mature individuals. Importantly, there are few populations with locally high abundance.

Severely fragmented

The *Guidelines* describe "severely fragmented" as the situation in which increased extinction risk to the taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations, which may go extinct with a low probability of recolonisation. The *Guidelines* consider fragmentation relevant in relation to flora if it increases the risk of disease or weed invasion by increasing edge effects, increases inbreeding effects, or decreases reproductive output.

For some parts of the species' range, if one population were to become locally extinct, there is little opportunity (in most cases) for recolonisation of that site. For example, the site at Falmouth is now considered locally extinct and based on present knowledge, there appears to be no local source of propagules. However, the fragmentation picture is blurred in some parts of the species' range. For example, there are several reported populations along the Midland Highway, Tunnack Road and Barton Road,

and along any one of these road features populations of *L. hyssopifolium* appear to become locally extinct but the species remains present at other sites and there is at least anecdotal evidence for a mechanism of hybridisation. For example, the sites along Tunnack Road may have been created by initial road works and while most sites are now apparently extinct, further road works may re-spread the species from some core sites. Similarly, along the Midland Highway, the loss of one site appears to be "compensated" by the detection of novel sites shortly after. Overall, the statewide distribution of *L. hyssopifolium* is meets the intent of severely fragmented.

Reservation status

Lepidium hyssopifolium is poorly reserved in Tasmania, and information on its reservation status has been variably interpreted. Kirkpatrick *et al.* (1991) had identified *L. hyssopifolium* as an unreserved species and suggested "Bells Lagoon" as a reservation site. This site is located north of Tunbridge Tier Road and is a naturally saline inland lagoon, wholly on private land, with no evidence that *L. hyssopifolium* ever occurred at the site.

TSS (2003, p. 2) states the following regarding the reservation status of the species: "A small population of *L. hyssopifolium* is reserved in the Township Lagoon Nature Reserve [at Tunbridge]. A population occurs in the Sydney Point Historic Site [on Preservation Island], two populations occur in Cemetery Reserves and one population occurs on a council managed Crown Reserve. A population has also been introduced to the Conara Roadside Park (B. Nicholson pers. comm). The largest population occurs in a Private Comprehensive, Adequate and Representative (CAR) Reserve".

The Preservation Island collection from 1976 may be from the Sydney Cove Historic Site (reserved under the Tasmanian *Nature Conservation Act 2002*), although the precise location from the island is unknown and only part of the island is reserved.

The status of the population reported from the Township Lagoon Nature Reserve (reserved under the *Nature Conservation Act 2002*) is uncertain, having not been seen since the original collection in 1991/1992 when only four plants were observed. This reserve has received considerable botanical survey in recent years by Threatened Plants Tasmania (Wildcare Inc.), Threatened Species Section (DPIPWE) and many field botanists, and if still present, *L. hyssopifolium* would likely have been reported.

The population at the Mt Nelson Signal Station is in a Public Reserve (under the Tasmanian *Crown Lands Act 1976*), although the status of this population is uncertain with recent surveys failing to detect the species.

Parts of the population in Oatlands technically fall within the Lake Dulverton Conservation Area (reserved under the Tasmanian *Nature Conservation Act 2002*), although most of the population occurs in highly modified habitats utilised for recreation rather than conservation.

Some sites occur in "reserves" managed by local government authorities. For example, the site at Howrah Beach is in a parkland area managed by City of Clarence and the sites on the Queens Domain are in an area managed largely for their bushland conservation values by City of Hobart (the status of the sites on the Domain is highly uncertain and has not been able to be confirmed despite several targeted surveys). One site (which is now presumed extinct) is in a local government reserve established as part of the Oakdowns development in the City of Clarence.

Wapstra (unpublished data) reviewed the status of the populations of *L. hyssopifolium* in cemeteries and concluded that of the four cemeteries from which the species has been reported (Lake River, Bagdad, Jericho, Bothwell), the species is only extant at Bothwell, where it is under threat from weed invasion and neglect. The assertion in TSS (2008) that "two populations occur in Cemetery Reserves" is considered inaccurate.

The status of this population at 'Annanvale' has not been checked for many years, and as one of the only sites in semi-natural habitat, this is considered a high priority.

Lawrence *et al.* (2008) reported that *L. hyssopifolium* occurs in five reserves: one formal reserve in the Flinders bioregion (presumably the Sydney Cove Historic Site), one formal reserve in the Northern Midlands bioregion (presumably the Township Lagoon Nature Reserve), one private reserve in the Northern Midlands bioregion ('Annanvale'), and one informal reserve in each of the Northern Midlands and South East bioregions. These authors allocated the species a status of 3a, which meant it was partially reserved because it is reserved in half or more of the bioregions in which the species occurs (indicates "comprehensiveness" and "representativeness"), a conclusion at odds with the obviously very low reservation status of the species. Apart from the fact that the status of most of the "reserved" populations is at best uncertain, none of the reserves in question have management plans that take account of the species (or any management plans).

Due to the almost exclusive occurrence of *L. hyssopifolium* on road verges, the opportunities for improving the reservation status of the species are limited. In addition, any sites on private property are not ideally suited to negotiating long-term conservation outcomes because of the potential conflicts between land management and the conservation requirements of the species (e.g., eventual need to remove mature pines that appear to form the key component of the habitat for the species).

Conservation management

Lepidium hyssopifolium occurs mainly in highly modified anthropogenic habitats, leading to some speculation that the species may not be native (Wapstra 2018). However, until definitive evidence is provided to confirm the origin of the species, it should be managed as a native. This then poses a complex question on the most appropriate form of management for a species that appears to be resilient and robust to high levels of disturbance.

Lepidium hyssopifolium was subject to a formal recovery plan (Tumino 2010), although this has not led to significant on-ground actions in Tasmania.

It is clear that the persistence of *L. hyssopifolium* in Tasmania will be reliant on actions (or inactions – see below) of local government authorities in combination with private landowners because most of the key extant populations are either on private land and/or council-managed road verges adjacent to private property, with only a small number of sites under the jurisdiction of a higher agency (e.g., Department of State Growth; Department of Primary Industries, Parks, Water & Environment).

In my opinion, there are four broad management options available for *L. hyssopifolium* in Tasmania, all of which are likely to be necessary in some combination to ensure the survival of the species.

OPTION 1: no management

Usually active management aims to maintain the population in its current state or improve its status (e.g., increase in numbers). The abundance of *L. hyssopifolium* at any particular site appears to be unrelated to management actions, except where the management has resulted in the loss of over-topping ornamental trees, which has generally resulted in a decrease in abundance or, in some cases, the complete loss of the population. Active management per se (e.g., active removal of weeds, implementation of a slashing regime) may be unwarranted for most subpopulations. However, without active intervention to prevent the loss or degradation of supporting habitat, localised subpopulations may continue to be lost.

OPTION 2: ex situ conservation

This is a genuine long-term conservation management option for the species. If there is little (or no) active management of most wild populations, ensuring that the species is represented in ex situ conservation programs is important. The species is already included in collections of the Millennium Seed Bank Project (Dennistoun Road site; J. Wood pers. comm.) and further collections would ensure that the genetic diversity of the species is represented.

It is interesting to note that this management option was recognised at the time of the earlier formal surveys of native grasslands of Tasmania, reported in *City Parks and Cemeteries: Tasmania's Remnant Grasslands and Grassy Woodlands* (Kirkpatrick *et al.* 1988, p. 156), with the authors stating: "We have failed to find recently recorded populations of *Lepidium hyssopifolium*, although we have grown it from Tasmanian seed from a specimen held in the Hobart Herbarium. All recent records of this species in Tasmania are from heavily modified roadsides. Its future in Tasmania depends on the reintroduction into places like the Domain, rather than reservation".

Unlike highly endangered plant species such as *Phebalium daviesii* Hook.f (Davies Waxflower) or *Eucalyptus morrisbyi* Brett (Morrisbys Gum) that lend themselves to ornamental plantings, *L. hyssopifolium* is not likely to be secured by domestic cultivation.

OPTION 3: benign neglect

This term is used to refer to the current management at almost all sites for *L. hyssopifolium* in Tasmania. That is, there is no active management of the species but routine management of the site supporting the species such as slashing of roadside grass does occur. Sites subject to benign neglect usually support the best performing populations of *L. hyssopifolium*. For example, many road verge sites (mainly council-managed) are obviously long-persistent and include multi-aged and locally abundant populations. The extreme of this is observed around Oatlands where the species is acting as a weed of gravel car parks and "lawns" in recreation areas. Other examples include sites such as York Plains Road, Nile Road, Stewarton Bridge and 'Ormley', where the species is performing extremely well, despite roadside management or complete neglect. That said, the species may have been lost from some localised sites such as three private cemeteries through benign neglect (although at two of these sites, the neglect took the form of the active removal of the key habitat feature).

Part of the argument for managing *L. hyssopifolium* by benign neglect is that there is little evidence that dedicating resources for active management of a site results in a manifest benefit to the species. On the contrary, it seems much more likely that for most sites, benign neglect for a decade or two will see the species in much the same state as the present.

OPTION 4: active management

Active management is appropriate for some sites where the species is directly threatened by proposed works or where there is a risk of removal of a key habitat feature (such as the shadowing ornamental tree). The Department of State Growth has historically managed, and continues to manage, several roadside populations of *L. hyssopifolium*. Some of these are long-term management sites that form part of the Department's Roadside Conservation Program, for example near 'Ormley' on the Esk Main Road, at which some active management (e.g., slashing, weed removal) occurs, combined with long-term population monitoring (pl. 4). At other sites, management is shorter-term, designed to minimise the risk of local extinction of a population during works. Recent examples of such sites include a culvert replacement on Fingal Rivulet (pl. 5) and surface resealing/weed spraying near Ouse (pl. 6): at both sites, barrier mesh or flagging was erected to successfully minimise risk of disturbance to the individual plants. Ongoing and complex monitoring was not considered warranted for these sites.

Localised active management may be beneficial for *L. hyssopifolium*. There is some evidence that the species may require some kind of disturbance to regenerate, which could include animals scratching in litter (Cropper 1987, Pyrke 1994). Pyrke (1994) simulated animal digging at a highly localised roadside population of *L. hyssopifolium* and found some short-term "resurrection" of the species. The degree to which this level of intervention can contribute to the overall conservation management of the species is not known.

A review of the formal conservation status of *Lepidium hyssopifolium*

Lepidium hyssopifolium is presently listed as endangered under both the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBCA) and the Tasmanian *Threatened Species Protection Act 1995* (TSPA). It is impractical herein to review the conservation status on the EPBCA because that would require substantially more information on its mainland Australian distribution than is available to the author. However, a review of its status on the TSPA is considered warranted because the present documentation has collated essentially all the available information on the species, something that has not been done since the species was first listed on the TSPA.

The Scientific Advisory Committee, established under the provisions of the TSPA, produced a set of "*Guidelines for Eligibility for Listing under the* Threatened Species Protection Act 1995" (DPIW 2008).

Lepidium hyssopifolium does not properly meet the intent of the criteria for the endangered category. A critical concept in this introductory statement of the *Guidelines* for the endangered category is a measure of "long-term survival". There is little doubt that *L. hyssopifolium* has demonstrated such survival, with an increase in the number of populations/locations over time. Another critical concept is knowledge of the "factors causing it to be endangered", which assumes sufficient knowledge to identify such threatening factors and the degree to which they may affect the "long-term survival" prospects of a species. In the case of *L. hyssopifolium*, some threatening processes have been identified, such as removal of overtopping ornamental pines and heavy stock grazing (Kirkpatrick *et al.* 1988, Kirkpatrick & Gilfedder 1998). Other threatening factors, such as the degree of impact from roadside management activities, are less well-documented. Irrespective of the factors involved, *L. hyssopifolium* has persisted at numerous sites in the "long-term" and it has remained present in Tasmania despite these factors operating. On this basis, it is argued that *L. hyssopifolium* fails the basic test of the endangered category. The species may meet some of the subcriteria but demonstration of this is difficult because many of the estimates of population parameters are missing or nebulous. For example, it is very difficult to justify that there has been an historic reduction in any of the population variables of greater than 50% in the last 10 years, or that there will be such a reduction projected to be met within the next ten years or three generations. The species does not meet the threshold of 5000 km^2 for extent of occurrence but does meet the threshold of 0.1 km^2 (10 ha) for area of occupancy. The species has a severely fragmented distribution but the extent of occurrence and area of occupancy is likely to remain quite stable, although the statewide population is likely to continue to show geographic and temporal transience. The concept of "quality of habitat" used in the *Guidelines* is interesting for a species such as *L. hyssopifolium*, which appears to rely on the maintenance of quite specific anthropogenic habitats. The overall extent of potential habitat will probably remain quite constant but there may be localised modifications that could cause the species to decline (the fact that it has persisted in the absence of over-topping conifers, however, makes this a hard to apply concept). The statewide population of mature individuals is estimated as fewer than 10 000 but it is difficult to justify that it is fewer than 2500 as used in the criteria.

Lepidium hyssopifolium better meets the intent of the criteria for the vulnerable category than the endangered category because the former category "copes" better with limited and nebulous estimates of various populations factors. The species also meets most of the thresholds used in the subcriteria (e.g., fewer than 10 000 mature individuals, area of occupancy less than 50 ha). However, taking a cautionary approach is recommended and it is suggested that the status of species should remain as endangered until more precise estimates of various population parameters are available.

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APPENDIX 1 — Summary of sites/subpopulations of *Lepidium hyssopifolium* within Tasmania. Location names are generally taken from database records or herbarium sheets; those in square brackets are allocated by the author where no location information was given. Habitat notes in quotation marks are taken direct from collection sheets or database records.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
STATUS: EXTANT			
'Potters Croft' [Dunalley]	T: private I: South East M: Sorell N: South	2008: 12 with unreported extent (not vouchered)	"*Eucalyptus globulus* on road verge".
opposite 470 Bay Road, Boomer Bay [Marion Bay]	T: local government I: South East M: Sorell N: South	2008: 20 with unreported extent (not vouchered) 2017: "still there" (A. North pers. comm.)	Unknown.
Burnt Hill Road (southeast) [Bream Creek]	T: local government I: South East M: Sorell N: South	2008: 10 with unreported extent (not vouchered) 2016: "still there" (A. North pers. comm.)	"Road gravel in culvert".
Bream Creek Road	T: local government I: South East M: Sorell N: South	2018: ca. 10 in ca. 10 m of road verge (vouchered at HO)	Bare road batter with sparse exotic grass under mature *Pinus radiata*.
Lyell Highway, ca. 2 km SE of Ouse	T: State Growth I: South East M: Central Highlands N: South	2016: 11 in unspecified area (not vouchered) 2017: 18 in ca. 2 x 2 m (vouchered at HO)	No information available (presume grassy road verge).
Hollow Tree Road (north) [Bothwell]	T: local government I: South East M: Central Highlands N: South	2014: 31 along ca. 250 m of road verge (vouchered at HO) 2017: 30 along ca. 250 m of road verge	No information available (presume grassy road verge).
Bothwell cemetery	T: private I: South East M: Central Highlands N: South	1991: no information with database records (not vouchered) 2006: 10 in unspecified area (not vouchered) 2017: 10s to 100s (vouchered at HO)	"Under exotic trees (northern site under an old *Pinus radiata*, western site under ornamental "macrocarpa"-type conifer around graves)".
Bothwell, N of fence between school and paddock	T: private I: South East M: Central Highlands N: South	2014: ca. 80 in ca. 200 m (vouchered at HO) 2017: no evidence but recently mown	Paddock edge under macrocarpa pines alongside school fence.
Nant Lane [Bothwell]	T: local government I: South East M: Central Highlands N: South	2014: 220+ in ca. 50 m of road verge (vouchered at HO) 2017: as 2014 (not vouchered)	Heavily grazed pasture verge of gravel lane.
Dennistoun Road [Bothwell]	T: local government I: South East M: Central Highlands N: South	2007: 44 in unspecified area (vouchered at HO) 2009: 25 in unspecified area (vouchered at HO) 2017: 2 only	Weedy/grassy road verge under remnant *Eucalyptus pauciflora*.
Dysart Drive (north)	T: local government/ private? I: South East M: Southern Midlands N: South	1991: no information with collection (vouchered at HO) 2002: 6 at base of two trees (vouchered at HO) 2009: 4 in unspecified area (not vouchered) 2017: 4	Under *Eucalyptus globulus* (planted?).

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
Maclaines Creek, Triabunna	T: State Growth I: South East M: Glamorgan-Spring Bay N: South	2004: 5 (not vouchered) 2006: ca. 60 (vouchered at HO) 2015: 1 (not vouchered) 2016: 50 (not vouchered)	Under ornamental pines.
Spring Hill, Midland Highway	T: State Growth I: South East M: Southern Midlands N: South	2014: 6 database records (one vouchered at HO) with 25+7+15+8+10 specified 2017: 3 sites of 43, 21 and 34 individuals	"Under *Eucalyptus globulus* [planted] and planted/weedy exotic *Acacia* species with dense grass on highway batter".
Edge of Lake Dulverton, Oatlands	T: Lake Dulverton Conservation Area & local government I: South East M: Southern Midlands N: South	1994: no information with collection (vouchered at HO) 2017: 100s of fertile plants and perhaps 1000s of seedlings (vouchered at HO)	Beneath pines at edge of lake but also numerous individuals scattered around picnic tables, rubbish bins and in the gravel of the road.
[Oatlands, Esplanade, between Barrack Street and Mill Point]	T: Lake Dulverton Conservation Area & local government I: South East M: Southern Midlands N: South	1994: no information with collection (vouchered at HO) 2017: 100s of fertile plants and perhaps 1000s of seedlings (vouchered at HO)	Under pines along road and lake verge.
[Oatlands, 'Weedington']	T: local government & private? I: South East M: Southern Midlands N: South	1999: no information with collection (not vouchered) 2017: 100s in front of property along road verge (vouchered at HO)	Sandy road verge under old pines.
Oatlands, Mahers Point	T: local government I: South East M: Southern Midlands N: South	2007: ca. 20+ (vouchered at HO) 2016: ca. 20+	Sandy gravelly soil under old macrocarpa pines.
York Plains Road, near Coffin Gully Creek	T: local government I: South East M: Southern Midlands N: South	1995: no information with collection (vouchered at HO) 2017: 18 in ca. 20 m of pine windbreak (vouchered at HO)	Under *Pinus radiata* and *Hespercyparis macrocarpa* over dense grass.
Barton Road at Stewarton Bridge	T: private I: Northern Midlands M: Northern Midlands N: North	1994: no information with collection (not vouchered) 2001: dense population 2017: 10s to low 1000s (vouchered at HO)	Under row of mature *Pinus radiata* on private property next to old stockyards and on gravel track.
Junction of Barton Road and Valleyfield Road	T: local government I: Northern Midlands M: Northern Midlands N: North	1994: no information with collection (vouchered at HO) 2017: 7 within 3 m of base of old macrocarpa (vouchered at HO)	Original site noted as being "under *Cupressus macrocarpa*" but this tree has now been chopped down (re-sprouting) and species occurs amongst dense grass on road verge.

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
Ormley, Esk Main Road	T: private & State Growth I: Northern Midlands M: Break O'Day N: North	1998: no information with collection (vouchered at HO) 2002: approximately two dozen plants close to drip line of tree (vouchered at HO) 2012: 60 in 50 m2 2016: 15 (12 in road reserve 3, over fence) 2017: ca. 200-250 (mature and seedlings); numerous seedlings missed amongst now quite dense grass; no estimate of individuals made on north side of fence on private property (but going very well – 10s to low 100s)	"Growing beneath the shadow of a cypress tree, with *Einadia nutans, Bromus diandrus, Plantago coronopus, Hypochoeris radicata, Dactylis glomerata*".
East of Fingal. Esk Main Road at Fingal Culvert no. B3169	T: private (State Growth works adjacent) I: Ben Lomond M: Break O'Day N: North	2014: ca. 25 plants around Pinus radiata (vouchered at HO) 2017: 50-100+ around original P. radiata and 1 to east under different P. radiata	"Sandy soil, weeds, grass beneath mature *P. radiata* on road verge".
[Macquarie Road, Cressy, road to pump station]	T: local government I: Northern Midlands M: Northern Midlands N: North	1994: no information with record (not vouchered) 2017: 7 in 10 x 2 m (vouchered at HO)	Southern side of road under mature macrocarpa pines (growing on private land) but *L. hyssopifolium* in gravel of road verge.
Nile Road	T: local government & private I: Northern Midlands M: Northern Midlands N: North	1994: no information with record (not vouchered) 2016: ca. 500 ("wheat field of seedlings") in 20-30 x 4 m of road verge (vouchered at HO) 2017: thinned out but counting was difficult because of recent roadside slashing	Eastern verge of Nile Road underneath a row of macrocarpa pines (growing on private land) but *L. hyssopifolium* in gravel/ slashed grass of road verge.
STATUS: UNCERTAIN			
Ralphs Bay	T: uncertain I: South East M: City of Clarence N: South	1931: 3 specimen sheets at HO (same collector, date and location) with no notes 2017: could not be re-located but original location unknown	Unknown.
Glebe, Oakdowns	T: Local Government Act Reserve I: South East M: City of Clarence N: South	2004: 2 records (3+ or 5 individuals) reported from a 1 x 2 m area (not vouchered) 2017: extensive search in vicinity of database records revealed only L. pseudotasmanicum and L. africanum	Light *Eucalyptus viminalis* grassy woodland with ornamentals and mown "lawns" (retained subdivision "reserve").
Howrah Beach, Wentworth Park	T: Crown I: South East M: City of Clarence N: South	2004: 4 individuals with unreported extent (vouchered at HO) 2017: extensive searching in vicinity of record failed to detect the species (L. africanum widespread and abundant)	"Amongst *Phragmites australis* behind dunes, beside track".

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
Domain	T: local government I: South East M: City of Hobart N: South	1995: no information with database records (not vouchered) 2014-2017: several searches by the author (and colleagues) have failed to detect the species anywhere on the Domain, with L. africanum and L. pseudotasmanicum being widespread and locally common	"Growth suppression zones in the shade of several cedars long the Soldiers Memorial Walk".
Burnt Hill Road (junction with Bream Creek Road) [Bream Creek]	T: local government I: South East M: Sorell N: South	1993: no information with database records (not vouchered) 2000: last seen but in decline (A. North pers. comm.) 2017: extensive search but not found	"Dense grass on road verge".
Knights Point, Windermere Bay Reserve [Claremont]	T: local government I: South East M: City of Glenorchy N: South	1986: no information with database records (not vouchered)	"Coastal point, with *Einadia nutans*".
Bridgewater Causeway	T: State Growth I: South East M: Brighton/Derwent Valley? N: South	1978: no information with collection (vouchered at CANB)	No information available.
Granton, 14km NE of New Norfolk. Derwent River, S bank (E side of bridge)	T: local government or TasRail I: South East M: City of Glenorchy N: South	1986: 20-25 in unspecified area (vouchered at HO)	"Between the roadside and railway line, south bank of Derwent River".
Cove Hill	T: private property I: South East M: Brighton N: South	2006: 2 in 1 x 1 m (vouchered at HO)	"Degraded *Eucalyptus viminalis* grassy woodland on dolerite".
Richmond	T: unknown I: South East M: City of Clarence N: South	1976: no information associated with collection (vouchered at QVMAG)	No information available.
Salmon Ponds ca. 8 km NW of New Norfolk	T: uncertain I: South East M: Derwent Valley N: South	1986: 25-50 in unspecified area (vouchered at HO) 2017: Extensive search of road verges of highway and road into Salmon Ponds only revealed extensive populations of L. pseudotasmanicum	"Roadside shoulder, with *Lepidium pseudotasmanicum*".
Lyell Highway, opposite Woolpack Road	T: uncertain I: South East M: Central Highlands N: South	1993: no information associated with record (not vouchered) 2017: general survey of road verges in area unsuccessful	No information available (presume grassy road verge).
'The Ouse'	T: unknown I: South East M: Central Highlands N: South	1918: no information with collection (vouchered at NSW)	No information available.
Bothwell	T: unknown I: South East M: Central Highlands N: South	1991: no information with collection (vouchered at HO)	No information available.

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
Bothwell tip	T: local government I: South East M: Central Highlands N: South	1991 & 1993: no information with database records or collection (1993 vouchered at HO)	"Heathy *Eucalyptus tenuiramis* woodland. Weedy area above tip face".
Hermitage	T: uncertain I: South East M: Central Highlands N: South	1984: no information with record (not vouchered)	No information available.
Bagdad, SE corner of training track	T: private I: South East M: Southern Midlands N: South	1990: no information with record (not vouchered)	Assume open paddock.
Bagdad [middle of training track]	T: private I: South East M: Southern Midlands N: South	1990: no information with record (vouchered at HO)	"In horse paddock".
Private Paddock, E Bagdad Rd	T: private I: South East M: Southern Midlands N: South	1999: ca. 5-10 in unspecified area (not vouchered)	"Paddock".
Dysart junction area	T: local government/ private? I: South East M: Southern Midlands N: South	1984, 1995 & 2003: no information with record (none vouchered) 2017: extensive search but not found	No information available.
[Tunnack Road, ca. 200 m W of 'Woodstock']	T: State Growth I: South East M: Southern Midlands N: South	1994 & 2002: no information with records (not vouchered) 2017: 7 in ca. 5 m of road verge	Dense grass on road verge.
'Kewstoke' York Plains	T: local government I: South East M: Southern Midlands N: South	1995: no information with collection (vouchered at HO)	"In tree planting, old conifers cut down, very weedy".
river bank at Ross	T: local government? I: South East M: Southern Midlands N: South	1981: no information with collection (vouchered at HO) 2017-2018: bases of all old pine trees around Ross township surveyed but only L. pseudotasmanicum located in historic church yard	"Around trunks of old pines".
'Annanvale' property [Tunbridge]	T: private I: Northern Midlands M: Northern Midlands N: North	1990: no information with collection (vouchered at HO) 1993: no information with collection (not vouchered)	"*Eucalyptus amygdalina* woodland, growing under trees of *Acacia dealbata*".
'Fosterville', Campbell Town [Ross]	T: private I: Northern Midlands M: Northern Midlands N: North	unknown date: no information with collection (vouchered at HO)	No information available.
Ellerslie property, Kingston Road	T: private I: Northern Midlands M: Northern Midlands N: North	1994: no information with collection (vouchered at HO) 2017: no evidence of Lepidium hyssopifolium (no Lepidium species) on either side of road beneath rows of mature pine	Row of mature pine trees on road verge.

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
[Cressy, west of school]	T: unknown (presume local government) I: Northern Midlands M: Northern Midlands N: North	1994: no information with record (not vouchered)	No information available.
'Glen Mavis', Deddington Road	T: local government I: Northern Midlands M: Northern Midlands N: North	1994: no information with collection (vouchered at HO)	"Beneath pines".
'Clarendon' [probably local government road]	T: uncertain (local government?) I: Northern Midlands M: Northern Midlands N: North	1994: no information with record (not vouchered) 2016 & 2017: both sides of road into 'Clarendon' were surveyed from Nile Road but the species was not detected	Mature pine trees over grass between road and paddocks.
'Blessington', west of O'Briens Road	T: private I: Ben Lomond M: Northern Midlands N: North	1995: no information with record (vouchered at HO)	"Farmyard".
Cove Point, Preservation Island	T: Sydney Cove Historic Site? I: Flinders M: Flinders Island N: North	1976: no information with record (vouchered at CANB)	No information available.
Tasmania [Archer]	T: unknown I: unknown M: unknown N: unknown	1840-1873: no information with record (vouchered at HO)	No information available.
Tasmania [Gunn]	T: unknown I: unknown M: unknown N: unknown	1830s-1840s: no information with record (vouchered at BER)	No information available.
STATUS: PRESUMED EXTINCT			
Mount Nelson Signal Station	T: Public Reserve (Parks & Wildlife Service) I: South East M: City of Hobart N: South	2002: 2 records (14 + 2 individuals) with unreported extent (vouchered at HO) 2017: could not be re-located despite extensive search of Signal Station area	Light *Eucalyptus globulus* grassy forest but highly modified with roads, car parks, buildings and mown lawns.
Black Snake Road, Granton	T: local government I: South East M: City of Glenorchy N: South	1991: 1 plant (vouchered at HO) 2017: could not be re-located despite extensive search along most of Black Snake Road	"Road verge under a large *Eucalyptus viminalis*".
Shones Corner, Risdon	T: State Growth I: South East M: City of Clarence N: South	1992 & 1993: no information with database records (not vouchered) 2002: ca. 40 (vouchered at HO) 2009: no longer present (internal State Growth report) 2017: extensive search but not found	Weedy bank of Risdon Brook under *Acacia dealbata*.
Hollow Tree Road (south) [Hollow Tree]	T: local government I: South East M: Central Highlands N: South	2011: 3 with unreported extent (not vouchered) 2014 & 2017: could not be re-located despite extensive search along ca. 500 m each side of database records on both sides of road	Dense grass on road verge.

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
Bagdad Uniting Church, Chauncy Vale Road	T: private I: South East M: Southern Midlands N: South	1999: <10 in unspecified area (vouchered at HO) 2017: could not be re-located (L. pseudotasmanicum present)	Under old radiata pine in grave yard.
Midland Highway, Bagdad	T: State Growth I: South East M: Southern Midlands N: South	1974: no information (vouchered at HO) 1982: common (vouchered at HO) 1991 & 1993: no information with database records (not vouchered) 2015: no longer present (A. North pers. comm.) 2017: not surveyed	"Sandy and mown road verge".
East side of road opposite the Bagdad Caltex Service Station, 10km N of the Pontville Bridge on the Midland Highway	T: State Growth I: South East M: Southern Midlands N: South	1984: 15 large plants and 30-40 seedlings and smaller plants along short distance of road verge (vouchered at HO) 1990: 50 (A. North pers. comm.) 2000: no longer present (A. North pers. comm.) 2017: not surveyed	"Dark brown clay-loam on mown road verge now dominated by introduced grass species. Adjacent paddocks extensively cleared and heavily grazed".
E Bagdad Rd jct, Midland Hwy	T: State Growth I: South East M: Southern Midlands N: South	1995 & 1999: no information with database records (not vouchered) 2017: could not be re-located (site now highly modified and "site lost to roadworks at this junction", A . North pers. comm.)	"Mown traffic island on west side of highway".
East Bagdad Road	T: local government I: South East M: Southern Midlands N: South	1991: "dense and thick stand" in unspecified area (vouchered at HO) 1999: 50 (vouchered at HO) 2017: extensive search along several hundred metres of each side of Esat Bagdad Road failed to find te species (L. pseudotasmanicum was present) and apparently the site was buried by Council road maintenan ce (fill) in the late 1990s (A. North pers. comm.)	"Under *Eucalyptus viminalis* on very disturbed roadside mound on side of road".
Dysart Drive (south)	T: State Growth I: South East M: Southern Midlands N: South	1994: 1 plant (vouchered at HO) 1995: no information with record 2007: no information with record 2017: could not be re-located	"Amongst roadside grasses and weeds in open".
Jericho cemetery	T: private I: South East M: Southern Midlands N: South	1991: no information with collections (two vouchers at HO) 2017: extensive search of cemetery revealed no individuals	"Degraded native grassland under *P. radiata* with *Vittadinia gracilis, Einadia nutans, Bromus sterilis*". Supporting pine tree now removed.
Jericho Road	T: local government I: South East M: Southern Midlands N: South	1999: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Baden, junction of Tunnack Road and Woodsdale Road]	T: State Growth I: South East M: Southern Midlands N: South	1999: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
[Tunnack Road near 'Woodside' property]	T: State Growth I: South East M: Southern Midlands N: South	2002: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Tunnack Road near 'Lint Hill' property]	T: State Growth I: South East M: Southern Midlands N: South	2002: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[ca. 500 m NE of Tunnack Road on 'Woodstock' near Tin Dish Rivulet]	T: State Growth I: South East M: Southern Midlands N: South	1994: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Tunnack Road, ca. 150 N of Black Gate Road junction]	T: State Growth I: South East M: Southern Midlands N: South	1996: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Tunnack Road, ca. 300 m S of entrance to 'View Banks']	T: State Growth I: South East M: Southern Midlands N: South	1996: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Tunnack Road, 'View Banks']	T: State Growth I: South East M: Southern Midlands N: South	1994: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Tunnack Road, ca. 350 N of entrance to 'Tramore']	T: State Growth I: South East M: Southern Midlands N: South	1994 : no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
Tunnack Main Road, S of Parattah	T: State Growth I: South East M: Southern Midlands N: South	1996: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.
[Tunnack Road, ca. 100 m SE of Beards Road junction]	T: State Growth I: South East M: Southern Midlands N: South	1994: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of road	Presume grassy/weedy road verge.

APPENDIX 1 — cont.

Location	(T)enure (I)BRA (M)unicipality (N)RM	Comments	Habitat
[junction Tunnack and Inglewood roads]	T: State Growth I: South East M: Southern Midlands N: South	1994 & 2002: no information with records (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database records on both sides of road	Presume grassy/weedy road verge.
[Parattah railway line]	T: TasRail I: South East M: Southern Midlands N: South	2002: no information with record (not vouchered) 2017: could not be re-located despite extensive search along ca. 200 m each side of database record on both sides of railway line	Presume grassy/weedy verge of railway line.
Township Lagoon Nature Reserve [Tunbridge]	T: Township Lagoon Nature Reserve (PWS) I: Northern Midlands M: Northern Midlands N: North	1991, 1992, 1993: 4 in unspecified area for 1991 record (1992 vouchered at HO) 2014-2017: several searches by the author and colleagues in the Township Lagoon Nature Reserve havefaield to re-detect the species	"*Themeda triandra* grassland in disturbed ground near tip".
Lake River Church	T: private I: Northern Midlands M: Northern Midlands N: North	1991: "common" (vouchered at HO) 2017: extensive search of cemetery revealed no individuals	"Under a large pine tree, well mulched ground". Supporting pine tree now removed.
Fingal, South Esk Highway, north roadside	T: uncertain I: Ben Lomond M: Break O'Day N: North	1991: no information with records (vouchered at HO) 2017: extensive search of road verge and in grassy cemetery yard nearly opposite this site only resulted in Lepidium pseudotasmanicum being found.	"Roadside under *P. radiata* with *Einadia nutans* and *Danthonia racemosa*". Trees have been removed and species lost (A. North pers. comm.), which was confirmed.
South Esk Highway, Fingal	T: uncertain I: Ben Lomond M: Break O'Day N: North	1991: no information with records (vouchered at HO) 2017: verges of main road through Fingal surveyed with no evidence of Lepidium hyssopifolium	"Under *A. dealbata* in weed infested site with *P. lanceolata, H. radicata*".
Fingal	T: uncertain I: Ben Lomond M: Break O'Day N: North	1984 & 1990: no information with records (not vouchered) 2017: see other Fingal records	No information available.
Falmouth	T: State Growth I: Flinders M: Break O'Day N: North	1992 & 1993 & 2002: no information with records (not vouchered) 1995: no information with record (vouchered at HO) 2002: 6 in 5 m2 2017: could not be re-located and it seems that the species has been absent since 2006 (A. North pers. comm.)	Grassy *Eucalyptus globulus* forest between road and paddock/ plantation.

BOB DINGLE – PATHFINDER AT WAR AND IN THE ANTARCTIC

by Herbert J.G. Dartnall

(with one figure, eight plates and one appendix)

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Bob Dingle (1920–2016) retired in 1975 to Swansea, Tasmania, after an adventurous and peripatetic working life. During the Second World War he served with Bomber Command. He was a wireless operator with 78 and 35 Squadrons, was decorated with the Distinguished Flying Medal and was commissioned. After the war he migrated to Australia and in 1950 joined the Commonwealth Bureau of Meteorology as a trainee weather observer with the express intention of serving in the Antarctic. Over the next 25 years he wintered seven times with the Australian and United States Antarctic programs, was awarded the Queen's Polar Medal with two clasps and served as the senior Australian weather observer for four years on the US Navy Ship *Eltanin*.

Key Words: Second World War, RAF pathfinder squadron, Antarctica, Heard Island, Davis, Wilkes, Plateau Station, Polar Medal.

INTRODUCTION

When Bob Dingle retired he moved to Swansea on the east coast of Tasmania where he quickly settled in as a generous and active member of this small town. It was pointless telephoning him during the day as he'd be pottering in his garden or out and about in the community. Mister Dingle, as he was universally known, helped deliver meals-on-wheels and library books to those confined to home, ferried local residents to Hobart for hospital appointments, visited the sick to see what he could do and for many years audited the local Anglican church accounts. His was a quiet, albeit active, retirement in stark contrast to his extremely varied, adventurous, exciting and peripatetic working life.

Born William Robert John Dingle on 5 November 1920 at home in Stithians, Cornwall, United Kingdom, Bob was the only surviving child of William Dingle and Miriam Jane Dingle, née Reed. There was a younger brother but he only lived for a few hours. Bob's father worked as a quarryman, where the rope and lashing skills he learnt whilst serving in the Royal Navy were in great demand. Bob was educated locally at the Helston Grammar School and on completion of his education in 1936 he secured a position with the General Post Office (GPO) as a sorting clerk and telephonist.

PLATE 1 — Aircraftsman W.R.J. Dingle, recently qualified Wireless Operator.

WAR SERVICE

With the advent of the Second World War Bob Dingle enlisted as an Aircraftsman second class in the Royal Air Force Volunteer Reserve on 10 October 1940. The following year he remustered as a Wireless Operator Air Gunner undergoing training at No 2 Signals School from 1 August 1941 and No 8 Air Gunnery School on 16 July 1942 (pl. 1). On 31 August 1942 Temporary Sergeant W.R.J. Dingle was posted to No 11 Operational Training Unit where he linked up with three New Zealanders who together formed the nucleus of a bomber crew. On 19 February 1943 they were posted to 78 Squadron based at Linton-on-Ouse, near York, after spending two and a half months at 1652 Conversion Unit, Marston Moor, training on Halifax bombers.

Over the coming months they would take part in what would become known as the Battle of the Ruhr, be involved with the firebombing of Hamburg and take part in the opening phase of the Battle of Berlin. As was the normal

operational procedure of the time, Bob flew his first three operations (ops) with other crews to gain experience.

Five ops later on 20 April 1943, Bob and his crew were posted to No 35 Squadron based at Graveley, Huntingdonshire. Although No 35 Squadron was a pathfinder squadron they flew with the main bomber force at first to gain further experience. But after Bob's twelfth op (to Bochum on 13/14 May) they flew as pathfinders – marking the target in front of the main bomber force and guiding them to the target. They turned back twice (on 11 June when the target was Munster and on 27 August when the target was Nürnberg), when their navigational equipment, IFF (indicator friend or foe), GEE (navigational equipment) and Y equipment (target finder) instruments blew up or otherwise failed, returning to Graveley early after jettisoning their bombs, markers and flares in the North Sea. The raid on Krefeld (Bob's sixteenth op on 21/22 June) was particularly disastrous for No 35 Squadron. Six of nineteen Halifaxes from 35 Squadron were lost that night – two were lost at sea, three were shot down by night-fighters and one just managed to stagger back and ditched some 30 miles east of Cromer after being damaged by flack. That crew was all saved but of the other five crews 20 were killed and 16 made prisoner of war (Chorley 1996). Bob and his crew were lucky and came through undamaged.

In late July Bomber Command turned its attention on Hamburg and over an eleven-day period, bombed the city on four occasions while the American Eighth Air Force targeted the docks, U-boat construction yards and various factories during the day. Bob and crew took part in all four raids. British losses over those four nights were light with 12 aircraft out of 791 lost on the night of 24/25 July, 17 out of 787 aircraft lost on the 27/28 July, 28 out of 777 on 29/30 July and a further 28 out of 740 on the 2/3 August (Middlebrook & Everitt 2000). These relatively light losses were attributed to the first use of windows or chaff – small strips of aluminium that are capable of producing false echoes on the enemy's radar. It was extremely hot and very dry on the second Hamburg raid and the bombing was highly concentrated. A massive firestorm raged for many hours killing an estimated 40 000 civilians (Middlebrook & Everitt 2000). Bob and crew were briefed for the Peenemünde raid (17/18 August) but for some reason, Bob could not remember why, they were stood down. August 1943 was a busy month and Bob and his crew took part in eight ops including two flying over the Alps to Turin so that by the end of that month they had completed their first tour of operations (30 ops). They immediately embarked on a second tour completing a further six ops over the coming three months that took them to the end of November 1943.

By mid-December 1943 Bob had flown 38 successful missions including six trips to Berlin. By then the crew was highly experienced, highly decorated (see appendix 1 for awards to Bob's crew) and five – including Bob – had been commissioned, though he was still flying as a Flight Sergeant. That month 35 Squadron was issued with new B Mark III Halifaxes and on 20 December four of these aircraft, including Bob's, were sent to attack Frankfurt.

PLATE 2 — "Time to go. Good luck everybody!". Painting by I.G. Taylor, 1995.

Halifax HX270 (M) took off at 1730 hours. Unfortunately, soon after take-off their airborne, ground scanning radar system (H2S) failed, so that they were unable to drop their target markers. Despite this they continued on and bombed the target with high explosives and incendiaries. Up until then the flight had been uneventful and no damage had been experienced from either the ground defences (flack) or night-fighters. However, on their way back home and shortly after crossing the German/Belgian border at an altitude of about 20 000 feet, one of the inner engines inexplicably caught fire. All attempts to extinguish the fire were unsuccessful, and when the fire spread to the main fabric of the aeroplane close to where the marker flares were stored, the pilot had no option but to give the order to bail-out (pl. 2).

Bob vividly recalled the barks and growls of countless dogs thousands of feet below as he floated down, disturbed by the sound of hundreds of aeroplane engines passing overhead. He landed alone in a ploughed field and after burying his parachute he began to walk in a SW direction until 0500 hours next morning. He spent the day hidden in a haystack near Wellen, Belgium, and at dusk he began walking again in a SW direction. About half an hour later he spoke to a farmer who took him home. Three hours later a man arrived with a bicycle who took him to a small town where he spent the night with a family whose name was never known to him. On the morning of 22 December he cycled to a farm where he met up with his flight engineer, Flight Sergeant William (Bill) Sinclair. Two members of this unnamed family then cycled with them to Neder Rechem some miles away, where they spent the night with the leader of the local underground. They had successfully linked up with the escape chain run by Walthère Dewé – a noted resistance leader during both world wars who was shot and killed some weeks later. Next day Bill and Bob caught a tram to Liège where they spent the next 13 days in hiding. On 5 January 1944 they were joined by Sgt H.L. Pike, an RAF Observer (navigator). The following day they were to be taken by train to Brussels but a random search of their train by the Gestapo revealed

that although their identity cards passed scrutiny they did not have work permits. Taken prisoner, they were initially held in the civilian prison at Liège for six days in solitary confinement. Bob was sent to Stalag IVB (Mühlberg) where he spent the rest of the war as a POW.

Stalag IVB was liberated by the Russians on 23 April 1945 but it was several days before Bob and the rest of his fellow POWs were allowed to cross the River Elbe and make contact with other allied troops. Their return journey to the United Kingdom was in three stages – they marched/walked most of the distance from Mühlberg to Halle; air transport from Halle to Brussels; then air transport from Brussels to an airfield near Harwell, Oxfordshire.

BOB'S MISSIONS

Bob took part in 41 operational sorties of which 38 were successful – safe return after bombing; plus two early returns due to instrument failure and his final op when his Halifax crashed in Belgium after bombing the target. Most were completed with his regular crew – James Henry Wright and Harold Matthews were his pilot and bomb aimer respectively on 38 occasions, Sydney Colin Rive Mackie was his navigator 37 times, Thomas Andrew Robson was Bob's rear gunner on 35 ops and Winston Barrington was his mid-upper gunner 31 times. Sidney Jackson, who was Bob's original flight engineer, suffered from chronic air sickness and was allowed to re-muster as an air traffic controller after completing 12 ops with Bob. He was replaced by S.J. Butler who flew nine ops with Bob and William Sinclair who completed 16 ops. All told, Bob flew operationally with a total of 30 Airmen. Of these 14 were killed in action, eight were made prisoners of war and seven were decorated. Four of Bob's regular crew were each awarded DFCs (see appendix 1). In addition, Kenneth James Rees, a mid-upper gunner who flew just once with Bob, received a DFM. James Bernard Anthony Scannell, who flew twice with Bob, was awarded both the DFM and DFC and Norman Francis Williams, an Australian who flew twice with Bob, was the most decorated non-commissioned officer in the Royal Australian Air Force in World War II, receiving the CGM (Conspicuous Gallantry Medal) whilst with 35 Squadron to go with the DFM and bar he had been awarded with 10 Squadron RAF.

EARLY ANTARCTIC SERVICE

Immediately post-war Bob served with a number of conversion units before joining 46 Squadron as a Flight Lieutenant flying Dakotas out of Stoney Cross. He was demobbed in late November 1946 and re-joined the GPO, taking an accountancy course at Bristol. In 1949 he came to Australia, securing a free berth on the MV *Somersetshire*. Sponsored by an aunt, who had settled in Griffith after the First World War, she had secured for him a job with the Murrumbidgee Irrigation Commission. On arrival Bob took one look at the set-up and left for Tasmania. He landed at Burnie where he was offered three jobs – as an insurance agent in Hobart, as a clerk with an aluminium mine on the Tamar River and, the one he accepted, as a clerk with the Mount Lyell Mining and Railway Company, Queenstown. The office work he undertook involved, amongst other duties, twice daily weather observations. Here he developed a lasting passion for the Tasmanian wild country and learned to tolerate the ever persistent rain and drizzle peculiar to the west coast of the Island State. All told he spent an enjoyable five months on the staff but this was not the life for him. A magazine article about Australia's sub-Antarctic islands – Heard Island and Macquarie Island – fired his interest so that when in March 1950 *The Mercury*, Tasmania's daily newspaper, carried an advertisement from the Commonwealth Bureau of Meteorology looking for trainee Weather Observers he applied with the express intention of going south.

He underwent a training course in Melbourne and was posted to RAAF Forest Hills near Wagga Wagga, New South Wales, to gain experience. January 1951 saw him on board HMAS *Labuan* on his way to Heard Island as part of the Australian National Antarctic Research Expeditions (ANARE) where he spent his first winter south. With hindsight, Heard Island was Bob's favourite Antarctic place – it had it all – the mixture of wildlife and vegetation, ice and snow, coastal and mountainous scenery. Whilst there Bob, Nils Lied and Ken Brown completed an epic 16-day trek, circumnavigating the island while doing a seal count (Law & Béchervaise 1957). This was a self-supporting expedition, without radio contact – for which they had to carry all their personal equipment, food, cooking stove and utensils, fuel and camping gear. In 1951 the glaciers radiating out from Big Ben flowed down to the sea. Since then the glaciers have retreated inland as a result of global climate change, so that large pro-glacial lakes or lagoons have formed on the land between the glaciers' snouts and the sea. The 1951 trip would now be impossible on foot as well as being precluded under health and safety considerations.

Back in Australia at Port Hedland Bob volunteered and was accepted for a second Antarctic tour on Macquarie Island but he was asked to defer this appointment and be part of the team to establish Australia's first Continental Antarctic Base, to be called Mawson Station during the 1953–54 summer. In February 1954 Mawson Station was established on an isolated outcrop of rock in MacRobertson Land. Bob was the sole Weather Observer in the party of ten (pl. 3). The party was relieved just over a year later and in January 1956 the *London Gazette* announced that:

> *The Queen has been graciously pleased, on the advice of Her Majesty's Australian Ministers, to approve the following awards of the Polar Medal for good services to all members of the Australian National Antarctic Research Expedition to Mawson, 1954–55.*

The Station Leader, who already had a Polar Medal, received an additional clasp dated Antarctic 1954–55. Bob and seven others received the medal with clasp dated Antarctic 1954–55, and the French Observer who had spent the year with them received the medal and clasp but it was not gazetted. Thus Bob added a Polar Medal to the Distinguished Flying Medal, 1939–45 Star, Air

PLATE 3 — Bob Dingle using a theodolite near Mawson Station in February 1955. Photograph courtesy of the Australian Antarctic Division.

PLATE 4 — Bob Dingle's unique group of medals left to right: Distinguished Flying Medal (1380581. ACT. F. SGT. W.R.J. DINGLE. R.A.F.), 1939–45 Star, Air Crew Europe Star, War Medal, ERII silver Polar Medal with two clasps Antarctic 1954–55 and Antarctic 1957 (WILLIAM R.J. DINGLE).

Crew Europe Star and War Medal he had received during the Second World War (Poulsom & Myres 2000) (pl. 4).

Bob spent the 1956 winter on Macquarie Island (pl. 5). Whilst there he was invited to be the Officer-in-Charge, and sole Meteorological Observer of Australia's second Antarctic Station to be established during the 1956–57 summer. The MV *Kista Dan* relieved Macquarie Island and, with Bob on board, arrived back in Melbourne on 11 December 1956. Six days later he was back on board the *Kista Dan* on his way to the Vestfold Hills, an ice-free oasis in Princess Elizabeth Land, where they began building Davis Station. A six day turn-around between two wintering years was most unusual; a year or two gap between consecutive overwinterings was the norm. At other times

PLATE 5 — Bob Dingle working the radiosonde recorder at Macquarie Island in 1956. Photograph courtesy of the Australian Antarctic Division.

between trips south, Bob had been sent by the Bureau of Meteorology to various RAAF stations around Australia, and to the Giles Weather Station in Central Australia that had been established to satisfy launch activities at the Woomera rocket range. On one of these gap years early in the sequence Bob took time out to go to New Zealand and visit the families of his bomber crew who had been killed during the war.

Just five men made up the Davis 1957 wintering party (pl. 6). As well as improving their prefabricated living quarters they carried out research projects in meteorology and geology, maintained an all-sky camera for auroral studies, trained dogs and explored the local area. A very full program had been successfully carried out and in January 1960 the *London Gazette* carried the announcement that all five had been recognised with the award of the Polar Medal or as in Bob's case an additional clasp dated Antarctic 1957 as he was already the recipient of this medal.

BOB'S ANTARCTIC MEDALLIONS

Today Australian Service Medallions are awarded to all members of Australian Antarctic expeditions who have wintered at Macquarie Island, Heard Island or on one of the continental Antarctic bases. The medallions are usually presented at the changeover ceremony when the first ship of the season arrives at the station. Bob wintered five times on Australian bases (fig. 1) and one might assume he would have been awarded five medallions. Given to acknowledge special recognition now that the Imperial Polar Medal was no longer being awarded to all, the first medallions were issued in August 1971 to all who had wintered south of 60°S and at Heard Island for the years 1968, 1969 and 1970; Macquarie Island personnel were added to the list in 1973.

PLATE 6 — The 1957 Davis party left to right Nils Lied, Bruce Stinear, Bob Dingle, Alan Hawker and William Lucas. Photograph courtesy of the Australian Antarctic Division.

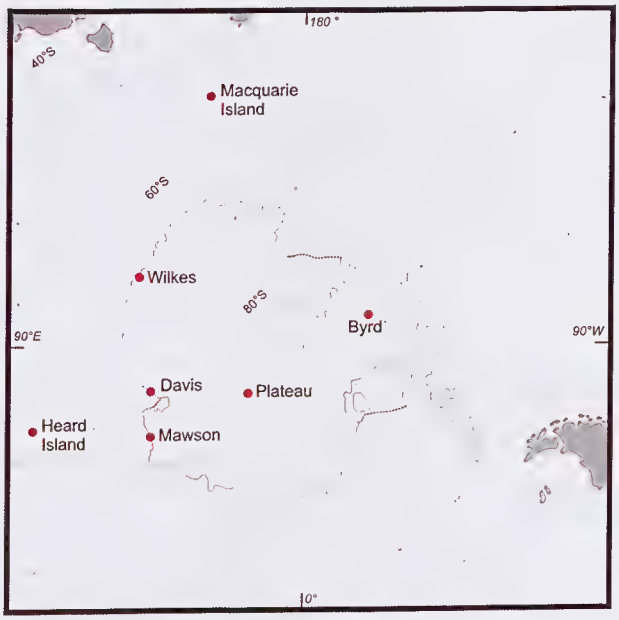

FIG. 1 — Where Bob wintered in the Antarctic.

In 1997 it was decided to retrospectively acknowledge the service of those men from 1948 onwards who had wintered but had not been awarded a Polar Medal. Bob, who had received the Polar Medal for his time at Mawson and Davis, thus only received three service medallions (pl. 7).

LATER ANTARCTIC SERVICE

In August 1958 Bob was granted special leave from the Bureau whilst attached to ANARE, and was appointed Officer-in-Charge of Wilkes Station following its transfer from the United States Antarctic Research Program (USARP) to ANARE in February 1959. In addition to his Officer-in-Charge duties Bob carried out a limited research program for the Meteorology Department at Melbourne University (UNIMET). This proved to be Bob's most difficult Antarctic posting. On 7 April 1959 one of the two diesel mechanics suffered a nervous breakdown and had to be confined and sedated. Three months after Henry Brandt went crazy the other mechanic, Hartley Robinson, was accidently crushed under the tracks of his tractor when it rolled down a slope. The loss of both diesel mechanics was a disaster but Antarctic expeditioners are invariably multi-skilled and highly adaptable and the Wilkes crew managed to keep the station up and running (Bowden 1997). Bob's father died on 31 December 1959 while he was at Wilkes.

In July 1961 Bob was again granted special leave from the Bureau of Meteorology whilst attached to UNIMET to join the USARP team at Byrd Station. Here he performed routine weather observations for the United States Weather Bureau (USWB) and carried out a series of snow drift observations for UNIMET during the 1962 winter.

Back in Australia he spent a year and a half at Willis Station (east of Cairns in the Coral Sea). Then, Willis station had a population of just three: two radio operators and one weather observer. In addition to his other duties Bob carried out routine weather observations for UNIMET. The fishing was good and the location was very desirable for amateur radio contacts with the rest of the world

PLATE 7 — Bob Dingle's Antarctic Service Medallion for his 1956 winter at Wilkes.

but his companions were quarrelsome. On his return he spent a very enjoyable six weeks on the summit of Mount Buller, just 200 km east of Melbourne, testing equipment for the CSIRO.

In December 1966 Bob was again seconded to the USARP and spent the 1967 winter at Plateau Station where he carried out routine weather observations for the USWB and carried on research for UNIMET. Plateau Station, at an elevation of 11 980 feet (3624 m) is located at 79°31'S, 40°E and is one of the most isolated and coldest places on earth. Summer temperatures (November to March) average –40°C (–40°F) and winter temperatures (April to October) average –70°C (–96°F) with an all-time low of –86.1°C (–123°F) recorded in June 1968, a few months after Bob had gone home. The base was only manned for three years with a team of four US Navy personnel to support four civilian researchers.

As a result of a cooperative program between the Australian and the US weather services Bob then spent the next four years, from August 1968 until March 1972, as the senior Australian weather observer on board the US

Navy Ship *Eltanin*. The cruises were almost exclusively in the Southern Ocean between South America and 70° East of Greenwich. Bob served on 18 of these cruises (numbers 35 to 52) doing oceanographic research across a wide range of marine science disciplines. Bob's mother, who had migrated to Victoria, Australia, after the death of her husband in 1959, died on 18 September 1969 in St Kilda.

BOB'S MISSING MEDAL

Bob's service with USARP at Byrd and Plateau stations would have made him eligible for the United States Antarctic Service Medal (US ASM) with "WINTERED OVER" clasp. He is featured in several US files concerning the initial distribution of the medal to US and foreign civilians, including being numbered Number 137 in a letter dated 25 May 1965 from the Office of the Assistant Secretary of Defence for International Security Affairs leading Colonel Albert F Gleim (Colonel USA Retired), in a personal communication, to conclude: "it seems virtually certain he was awarded and issued the medal ... but there is nothing to absolutely to confirm this (such as a report of a presentation ceremony or a receipt)". Then Bob ought to have been awarded the Antarctic Service Medal with bronze "WINTERED OVER" in accordance with the Assistant Secretary's letter and sent a gold (coloured) clasp to replace the bronze one after completing his second year at Plateau station. Bob never received his medal and I can only conclude that for some unexplained reason they were never issued or were lost in the post.

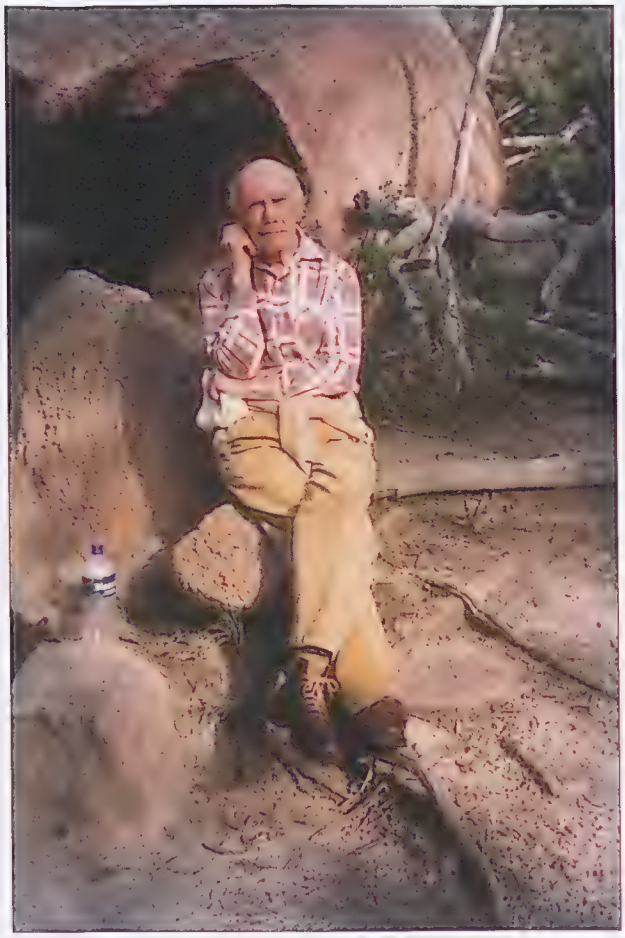

PLATE 8 — Bushwalking in Tasmania, early 1990s.

RETIREMENT

Bob served as weather observer on Norfolk Island until April 1973 and then spent the next two and a half years attached to the Special Services Section of the Tasmanian Regional Bureau in Hobart. He resigned from the Australian Meteorological Service in December 1975, aged 55 and retired to Swansea, thus beginning a long and happy retirement. Periodically he would take off on bushwalking trips around Tasmania (pl. 8), and while at home he enjoyed listening to his extensive collection of classical symphony and choral music on tape. He was an accomplished photographer and held a number of slide shows for local volunteer groups including the fire brigade and SES. Indeed a book of his Antarctic photographs was published a few years ago (Dingle 2011). He was interviewed in 2011 by Ingrid Mcgaughey as part of the ANARE Club's Oral History Project; copies of the record of interview have been lodged with the Australian Antarctic Division, the Tasmanian Museum and Art Gallery and the ANARE Club.

In addition to these indoor and outdoor solitary activities, Bob kept in touch with his ANARE colleagues and Met Bureau workmates. He was a regular attendee at ANARE Midwinter Dinners, and a good correspondent with those further away. In 2012 he sold up and moved into the May Shaw Nursing home in Swansea on 4 June. William Robert John Dingle died after a long and extraordinary life on 5 September 2016, aged 95.

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My thanks to the Dingle family, especially Mrs Janet Ivey for details of Bob's early life, and to Bob's Swansea neighbour Mrs Margo Spurr for information on Bob's period of retirement. I also thank my daughters Dr Jennifer Selkirk-Bell and Ms Katherine Selkirk for mapping and editorial skills, and my wife Dr Patricia Selkirk for her support and enthusiasm for this writing project.

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(accepted 6 November 2018)

Appendix 1 — The fate of the crew of HX270 (M)

Bob was the last to leave the stricken aircraft. He followed the bomb-aimer and navigator through the escape hatch forward of the front turret while the engineer and mid-upper gunner exited through the entrance hatch. The rear-gunner Pilot Officer Thomas A. Robson, who vowed he would never jump, stayed on board and died along with the pilot Flight Lieutenant James H. Wright when the plane crashed. The navigator Flight Lieutenant Sidney C.R. Mackie also died when his parachute failed to open. Three fatalities, all New Zealanders, all decorated with the Distinguished Flying Cross. Their remains were subsequently reburied together in Heverlee War Cemetery (Chorley 1996).

Of the three other members of Bob's crew, Flight Sergeant William MacRae Sinclair (Flight Engineer) was captured with Bob at Liège. The mid-upper gunner Sergeant Winston Barrington was captured on 6 January 1944 and interned with Bob in Stalag IVB. His widowed mother Florence had remarried a German in 1933 and lived in Austria during the Second World War. On learning of Winston's incarceration in Mühlberg she moved there and got herself smuggled into the camp and with her breasts taped down succeeded in passing herself off as a man until the camp was liberated (Stoneley 1980, Vercoe 2006). Florence's story, with a degree of poetic licence was been made into a 1985 TV series with the title "Jenny's War", and a 1992 film of the same name starring Dyan Cannon in the lead role and Hugh Grant playing the part of Winston. Pilot Officer Harold Matthews DFC, bomb aimer, evaded capture for four and a half months until captured at Dinant on 10 May 1944. He was incarcerated in Camp L7 (WW2 RAF Evasion and capture files, Public Records Office).

Decorations awarded to members of Bob Dingle's crew (pl. A1)

Distinguished Flying Cross *London Gazette* 8 October 1943, page 4449
Acting Flight Lieutenant James Henry WRIGHT (NZ 414717) RNZAF No 35 Squadron
Pilot Officer Sidney Colin Rive MACKIE (NZ413713) RNZAF No 35 Squadron.
Pilot Officer Harold MATTHEWS (149150) RAFVR No 35 Squadron

One night in September 1943 Flight Lieutenant Wright and Pilot Officers Mackie and Matthews were pilot, navigator and air bomber respectively of an aircraft detailed to attack Mannheim. The operation demanded a high degree of skill and the success achieved reflects great credit on the efforts of these members of aircraft crew who executed their task faultlessly. They have taken part in many previous operations and have always displayed courage, determination and devotion to duty of a high order.

Distinguished Flying Medal *London Gazette* 16 November 1943, page 5026
Acting Flight Sergeant William Robert John DINGLE (1380581) RAFVR No 35 Squadron

Distinguished Flying Cross *London Gazette* 10 December 1943, page 5381
Pilot Officer Thomas Andrew ROBSON (NZ 414893) RNZAF No 35 Squadron.

PLATE A1 — Members of Bob Dingle's crew. (A) Flight Lieutenant J.H. Wright, (B) Flight Lieutenant S.C.R. Mackie and (C) Pilot Officer T.A. Robson (photo credit *The Weekly News*, the Airforce Museum of New Zealand).

OBITUARY: PROFESSOR PATRICK GERARD QUILTY AM

by Ross R. Large, June Pongratz and Margaret Davies

(with one plate)

Large, R.R., Pongratz, J. & Davies, M. 2018 (14:xii): Obituary: Professor Patrick Gerard Quilty AM. *Papers and Proceedings of the Royal Society of Tasmania* 152: 61–70. ISSN 0080–4703. College of Sciences and Engineering, School of Natural Sciences, University of Tasmania, Private Bag 79, Hobart, Tasmania 7001, Australia (RRL*); 15 Rosehill Crescent, Lenah Valley, Tasmania 7008, Australia (JP); 4/2 Fisher Lane, Sandy Bay, Tasmania 7005 Australia (MD). *Author for correspondence. Email: Ross.Large@utas.edu.au

Patrick Quilty had a long and distinguished career in Earth Science and Antarctic exploration. His many contributions to The Royal Society of Tasmania have been very significant and highly regarded by members and Council. In 1986 he was elected the senior vice-president of The Royal Society of Tasmania, when the Governor was president. He became president of the Society again in 2010 and was the Chair of the RST Foundation for several years besides being member of the Awards Committee, including serving as chair. In 1996 he received The Royal Society of Tasmania Medal for his scientific achievements and service to the Society. In 2011 he convened the highly successful two-day Mawson Symposium for the Society.

Professor Patrick G. Quilty AM.

He was an extremely active member of the Tasmanian Division of ANZAAS, as well as of the Association of Australasian Palaeontologists and the Geological Society of Australia.

Patrick obtained his BSc (Hons) from the University of Western Australia and PhD from the University of Tasmania. He spent six years in the oil industry as a palaeontologist with West Australian Petroleum (WAPET), followed by five years as a lecturer at Macquarie University. His first visit to Antarctica was in 1965/66 with the University of Wisconsin, followed by a field trip to Macquarie island in 1968, with a party that identified the island as a unique piece of uplifted oceanic crust. From 1981 to 1999 Pat was Chief Scientist for the Australian Antarctic Division and ANARE. He made a total of 14 working trips south, including three summers in the Vestfold Hills investigating fossil whales he had originally discovered in 1989, and participated in three ANARE marine science voyages.

During his period at the Australian Antarctic Division, Patrick was very active in international Antarctic leadership, serving as a vice-president of the Scientific Committee on Antarctic Research (SCAR) for four years, and chairing the organisation of the XXth meeting of SCAR in Hobart in 1988, as well as symposia on the Vestfold Hills (1984) and Macquarie Island (1987).

Patrick Quilty has published over 200 scientific papers, including several in the last three years with others in the final stages of submission. He became an Honorary Professor in Earth Sciences and IMAS at the University of Tasmania in 2010 and has been a Distinguished Visiting Professor at California State University. His many awards include Member of the Order of Australia (AM), U.S. Antarctica Service medal, Inaugural Distinguished Alumnus of the University of Tasmania, and the Phillip Law Medal of the ANARE Club. Two Antarctic geographic features and five fossil species have been named in his honour. Particularly in his later years, Patrick was a regular commentator on a broad array of Antarctic matters with TV, radio and the press, on tourist vessels and on Antarctic overflights.

Honorary Research Professor Patrick Quilty was a warm hearted and generous man, who epitomised the mission of our Society (the advancement of knowledge), and devoted much of his valuable time to Society matters. He will be greatly missed by our members.

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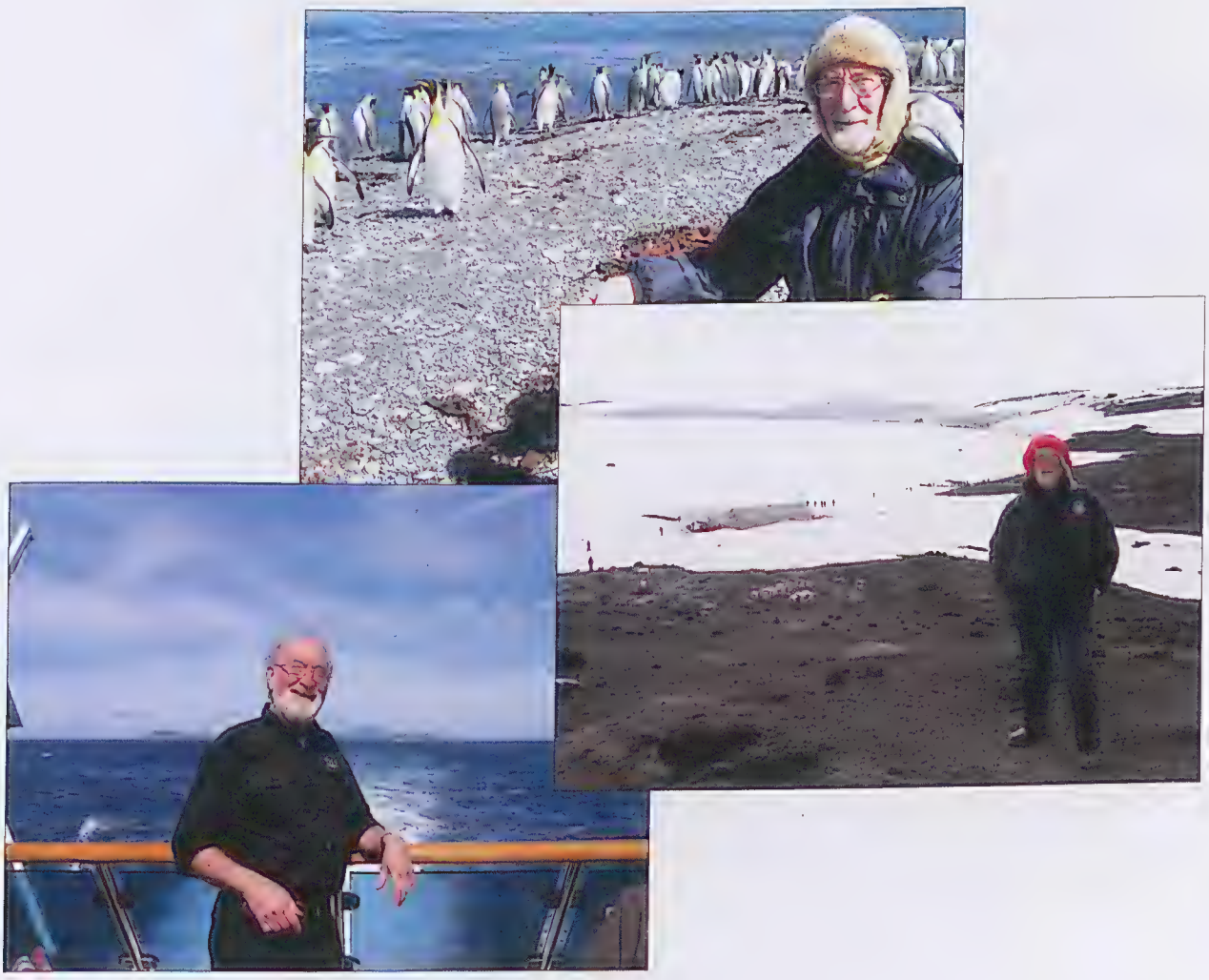

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'POPULAR' ARTICLES

A sample only. Includes books and popular 'magazines' to which P.G. Quilty made contributions.

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Coordinator: Papers included in *Issues* designed for upper high school students and goes to about 75% of Australian high schools.

1978: Hodgkin, E.P. – An environmental study of the Blackwood River estuary, W.A. W.A. Department Conservation Environment Report No. 1.

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1979: Reader's Digest – *Library of Essential Knowledge* Australianising a British three-volume series.

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Garner McLennan (Sydney) – Consultant in production of *National Geographic* educational video for US/Canada (in progress, 1990/1991)

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